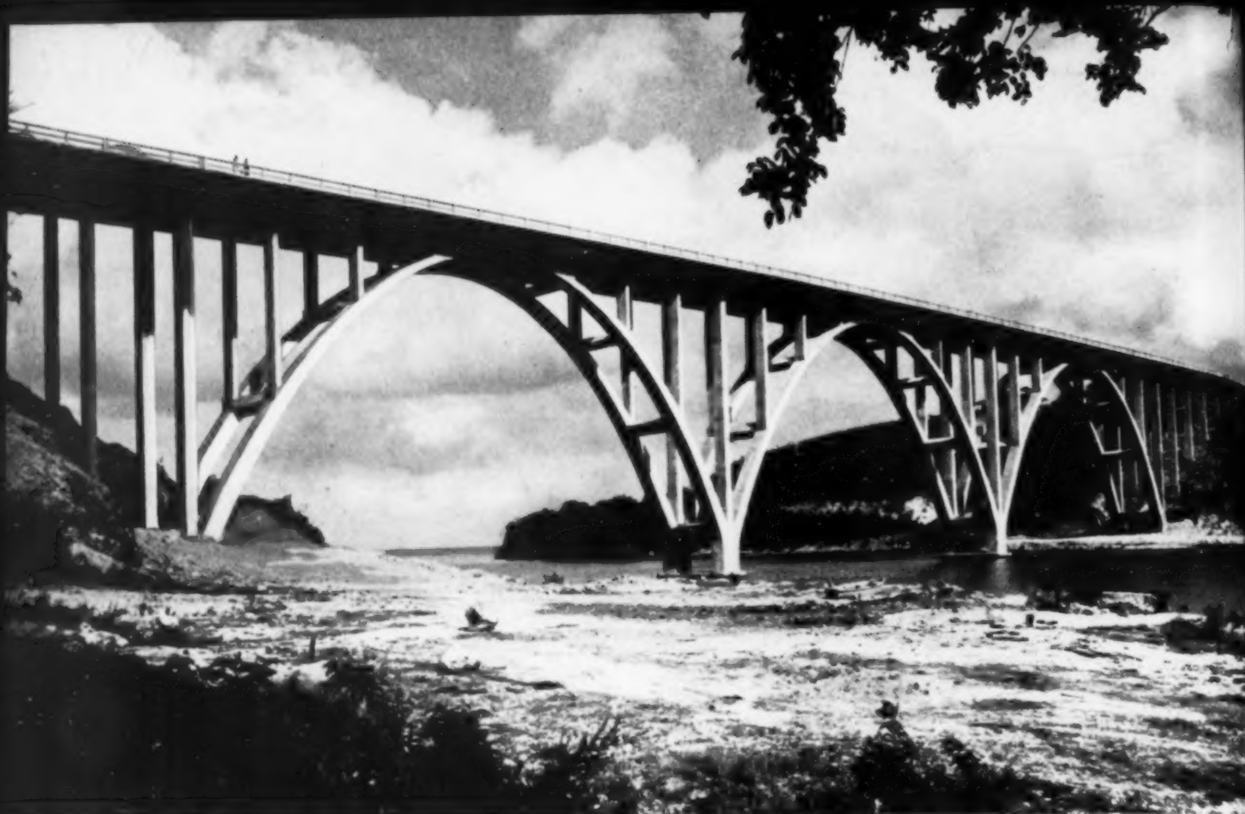
CIVIL ENGINEERING

...the art of directing the great sources of power in Nature for the use and convenience of man. —Tredgold

1852
CENTENNIAL of ENGINEERING
1952



Structure designed under direction of Ing. Jose Menendez of Comision de Fomento Nacional; Manuel Ray, Resident Engineer.

Raymond FORGES AN IMPORTANT LINK IN HAVANA-VARADERO HIGHWAY

This graceful reinforced concrete bridge spanning the Canimar River in Cuba was completed by Raymond ahead of schedule. Hailed as one of the most functionally beautiful structures in the Caribbean, the three-span bridge is 115 feet high and has an overall length of 973 feet—a fitting symbol of the wide variety of Raymond activities.

Constructed for Cuban Comision de Fomento Nacional by Raymond Concrete Pile Company of South America

a wholly owned subsidiary of Raymond Concrete Pile Co.

AROUND THE WORLD
FOUNDED 1897

Raymond

CONCRETE PILE CO.

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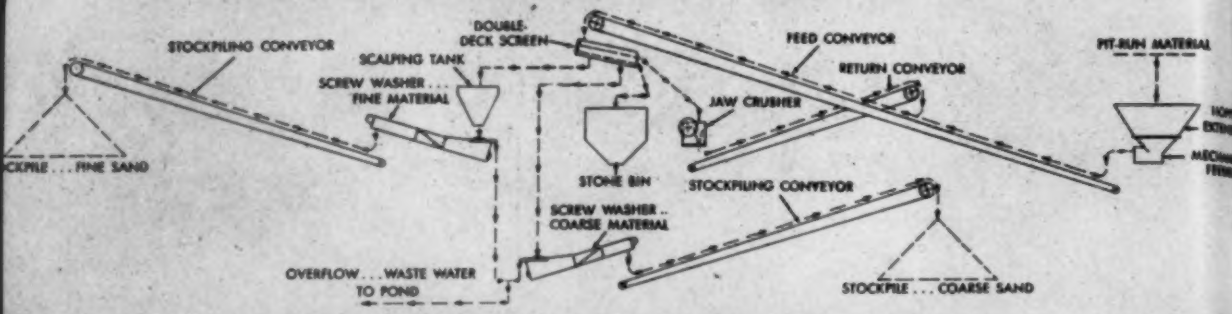
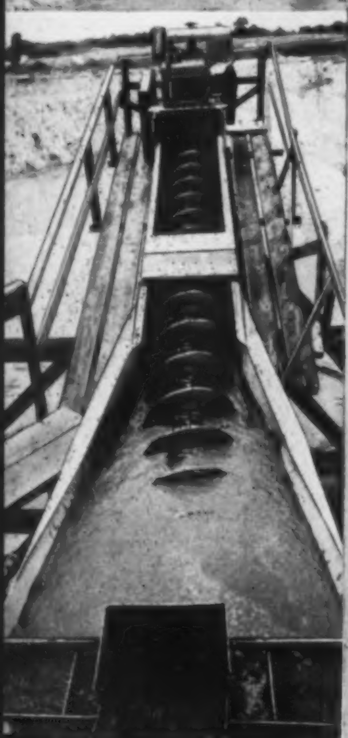
Engineered for Maximum Production Per Dollar of Investment

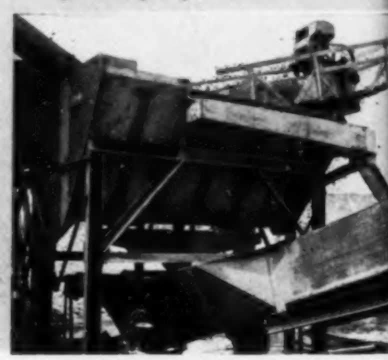




"Adding washing equipment to what was already a highly efficient crushing and screening plant has made my Austin-Western set-up DOUBLY SUCCESSFUL and PROFITABLE."
Edward Schneider, Elgin, Illinois

Pit-run gravel is conveyed to a screen to which water has been piped, where stone already down to size is removed and spouted to the bin. Oversize goes to a jaw crusher, and from there is returned by conveyor to the screen, closing the circuit. Coarse sand is spouted to a screw washer where, through controlled water turbulence, the coarser, heavier material, washed clean, settles to the bottom and is taken out by the screw. The finer sand, together with silt and debris, is held in suspension, and goes with the water to a large settling tank where the sand settles to the bottom. Then, with some of the water, it goes to the final washer where the fine sand is again thoroughly cleaned. As it settles, it is taken out by screw conveyor. Washed material, from which silt, clay and vegetation have been removed, always brings TOP prices!

Whatever your requirement, there's an Austin-Western plant to meet it . . . a plant that means MORE ROCK for LESS MONEY. Why not talk things over with our engineering department?



-up of screw washer for coarse material

Return conveyor provides closed-circuit operation

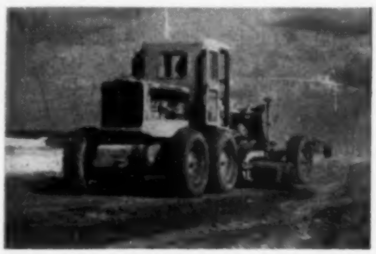
View of settling tank and screw washer for fine

Cecil Field "Beefed up" for Jets

BIG YELLOW TASK FORCE HELPS CONSTRUCT NEW 9,400-FOOT RUNWAYS ON THE DOUBLE

A Navy pilot returning to Cecil Field after a year's absence would notice quite a change in the layout of his old Florida base. He'd see two new runways, constructed to accommodate present and future jet airplanes. Each runway is 9,400 feet long and 200 feet wide, and land is cleared 750 feet from their center lines and ends to provide a 50-1 glide angle.

This pair of runways marks the start of an expansion program to make Cecil Field a master jet field. For the initial 1,500,000-yard earthmoving project, contractor L. G. Defelice & Son, Inc., assembled a task force consisting mainly of "Caterpillar" units. Strategic use of these big yellow machines – tractors, wagons, scrapers, 'dozers and motor graders – helped speed construction in difficult terrain. Ten big new 275-HP DW20 Tractors with No. 20 Wagons bore the brunt of the work.



Good haul roads are the responsibility of this "Cat" No. 12 Motor Grader, one of several No. 12s on this job. More than 9 out of 10 "Cat" Motor Graders ever built are still in use.

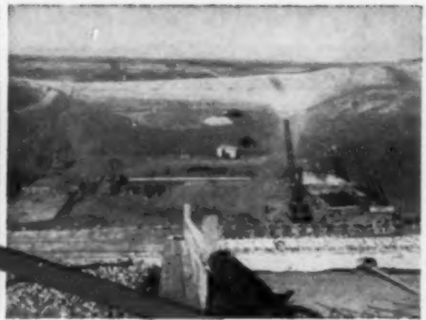
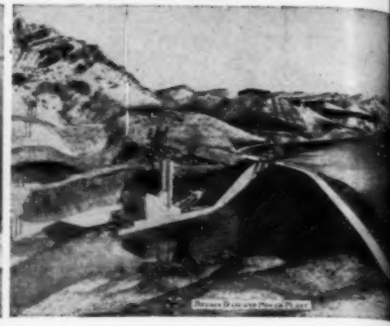
In spite of very tough going in sticky sand, the DW20 teams came through with outstanding performance. Here are some typical figures from this job. After being loaded by a belt conveyor loader, the DW20 units barreled off with average loads of 23 cubic yards each. On a 4,500-foot to 5,000-foot round-trip haul, each averaged 6 trips every hour per 10-hour day. "These units far exceeded our expectations," said Project Manager Fred Sebastian. "They can't be beat for power, speed and efficiency."

Sticky sand is being gobbled into the jaws of this "Cat" No. 80 Scraper, push-loaded by a D8 and No. 8S 'Dozer. Ejection of heaped sand was speeded by the No. 80's high apron lift.

"Caterpillar" equipment used on other phases of the operation included D8s and No. 80 Scrapers on leveling work, No. 12 Motor Graders maintaining haul roads, a D8 pulling a compactor and other D8s and 'Dozers leveling fill dirt. Successful contractors find that this assignment of heavy-duty tools to the zones for which they're best fitted results in higher production at lower cost. They also observe that standardization on the big yellow line pays off other ways. One is the fact that maintenance problems are centered in the capable hands of the nearby "Caterpillar" Dealer. He's a convenient source of service or information at all times!

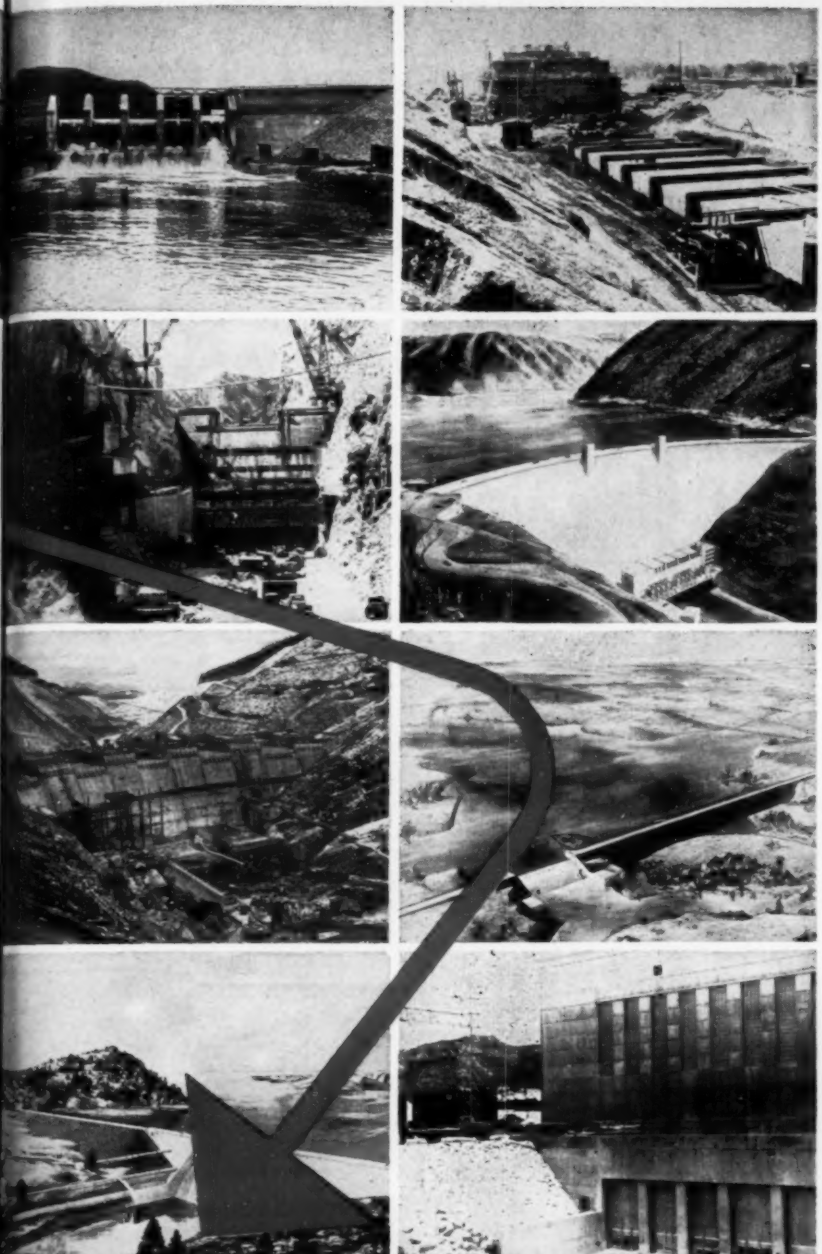
Zooming across sand on big rubber tires, two "Cat" DW20s with No. 20 Wagons pass on a 4,500-foot to 5,000-foot round-trip haul. Each unit averages 6 trips per hour with an average load of 23 cubic yards.

CATERPILLAR TRACTOR CO., PEORIA, ILLINOIS







This is a partial list of Protex projects:

Morrison-Knudsen Co., Inc., Shoshone, Wyo. Boysen Dam, U. S. Bureau of Recl.

Johnson-Winston-Kiewit, Contractors, Fort Gibson, Okla. Fort Gibson Dam (690,000 yds.) U. S. Corps of Engineers

Nelson Construction Co., Alma, Nebr. Harlan County Dam (430,000 yds.) U. S. Corps of Engineers

Al Johnson Construction Co., Denver, Colo. Cherry Creek Dam, U. S. Corps of Engineers

Lytle-Amis Construction Co., Cambridge, Nebr. Medicine Creek Dam U. S. Bureau of Recl.

Hubert H. Everist, Sr., Contractor, Westley, Calif. Delta-Mendota Canal, U. S. Bureau of Recl.

Moxon Construction Co., Tallulah, La. Pearl River Lock No. 1, U. S. Corps of Engineers

McNary Dam Contractors Plymouth, Wash. McNary Dam (760,000 yds.) U. S. Corps of Engineers

Mittry Brothers Construction Co., Hulah, Okla. Hulah Dam, U. S. Corps of Engineers

Peter Kiewit & Morrison-Knudsen, Estes Park, Colo. Colorado Big Thompson Project U. S. Bureau of Recl.

Lytle & Green Construction Co., Glen Ullin, N. D. Heart Butte Dam, U. S. Bureau of Recl.

T. L. James & Co., Bush, La. Pearl River Lock No. 2, U. S. Corps of Engineers

Peter Kiewit & Sons Co., Fresno, Calif. Friant-Kern Canal, U. S. Bureau of Recl.

Dorena Construction Co., Cottage Grove, Ore. Dorena Dam, U. S. Corps of Engineers

Guy Atkinson Co., Inc., Walla Walla, Wash. Mill Creek Project U. S. Corps of Engineers

Utah Construction Co., Hot Springs, S. D. Angostura Dam, U. S. Bureau of Recl.

Morrison-Knudsen Co., Inc., Casper, Wyo. Kortes Dam, U. S. Bureau of Recl.

Guy Atkinson & J. A. Jones Cons. Co. Hanford, Wash. U. S. Atomic Energy Plant, U. S. Corps of Engineers

Morrison-Knudsen & M. H. Hasler Tracey, Calif. Delta-Mendota Canal, U. S. Bureau of Recl.

Gordon-Bressi-Bevanda, Estes Park, Colo. Estes Park Dam, U. S. Bureau of Recl.

A. L. Alley & Son, Contractor, Pickstown, S. D. Fort Randall Dam (paving work) U. S. Corps of Engineers

Adler Construction Co., Madras, Ore. Dickinson Dam, U. S. Bureau of Recl.

Horner & Switzer Construction Co., Hale, Colo. Bonney Dam, U. S. Bureau of Recl.

Young & Smith Construction Co., Paonia, Colo. Paonia Dam, U. S. Bureau of Recl.

S. B. H. U. Co., Hot Springs, Ark., Bailey Mountain Tunnel, U. S. Corps of Engineers

U. S. Engineers, Fort Peck Dam

McCarthy Improvement Co., Pickstown, S. D. Fort Randall Dam, U. S. Corps of Engineers

Al Johnson Construction Co., Pickstown, S. D. Fort Randall Dam, U. S. Corps of Engineers

Silas Mason Co., Pickstown, S. D. Fort Randall Dam, U. S. Corps of Engineers

S. A. Healy, Riverdale, N. D. Garrison Dam, U. S. Corps of Engineers

Adler Construction Co., Dickinson, N. D. Dickinson Dam, U. S. Bureau of Recl.

Peter Kiewit & Morrison-Knudson, Riverdale, N. D. Garrison Dam, U. S. Corps of Engineers

Hamilton, Williams & Noonan, Beaumont, Texas Neches River Dam, U. S. Corps of Engineers

Consolidated Builders, Inc., Mill City, Ore. Detroit Dam, U. S. Corps of Engineers

T. L. James Co., Contractors, Fort Worth, Texas Fort Worth International Air Port

General Shea-Morrison, Hungry Horse, Mont. Hungry Horse Dam (3,100,000 yds.) U. S. Bureau of Recl.

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The bridge that raised itself

DELAWARE MEMORIAL BRIDGE, Wilmington, Delaware is one of the most important bridges in the country. It connects with the New Jersey Turnpike and shortens the time between New York and Washington. It carries the four-lane U. S. Route 40 for more than two miles between Pennville, New Jersey and New Castle, Delaware eliminating a very severe bottleneck. Approximately 4,000,000 motor vehicles will use the bridge annually.

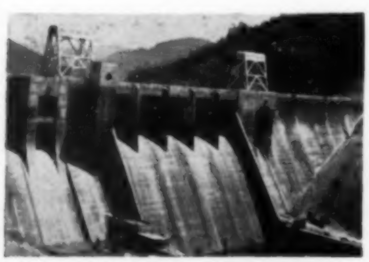
SUSPENDING THE FIRST CABLES. Before any spinning of the main suspension cables could begin, four 2-inch American Tiger Brand Wire Ropes were strung from anchorage to towers and from tower to tower. On these were placed Cyclone Chain Link catwalks with wire rope railings to provide safe footing for the workmen.

Next a wire rope tramway system was installed to carry the hauling cable for the spinning wheels. The photo shows workmen picking the individual wires from the spinning wheel to form the main suspension cable. The 436 wires in each strand of the main cable are, in reality, two continuous wires which are connected to the anchorage at both ends by means of eyebars. The end of the wire from each successive reel was spliced to the end of the wire from the next reel and the ends of the last pair of wires of the strand were spliced to the ends of the first pair. It took 19 of these strands to form each of the main cables.

Interesting Facts

Total length of bridge—10,765 feet
Length of Main Span—2,150 feet
Length of each suspended side span—750 feet
Height of towers above piers 417 feet—about equal to height of a 35-story building
Clearance of main span above water—175 feet
Size of main wire cables—19¾ inches in diameter
Size of wire rope suspenders—2 inches in diameter
Total length of suspenders—56,000 feet
Estimated weight of superstructure—73,141,500 pounds
Total estimated cost of bridge—$43,900,000

Bridge Substructure, Washington, D.C.



Flood Control Dam, Pennsylvania

Fresh water aqueduct, New York

New parts depot and general sales district office of International Harvester Company at Denver, Colorado.

In the three Allied shops, located at strategic points, skilled men and abundant plant equipment are available to fabricate the steel in record time.

On-location erecting crews know how to get the structure up fast.

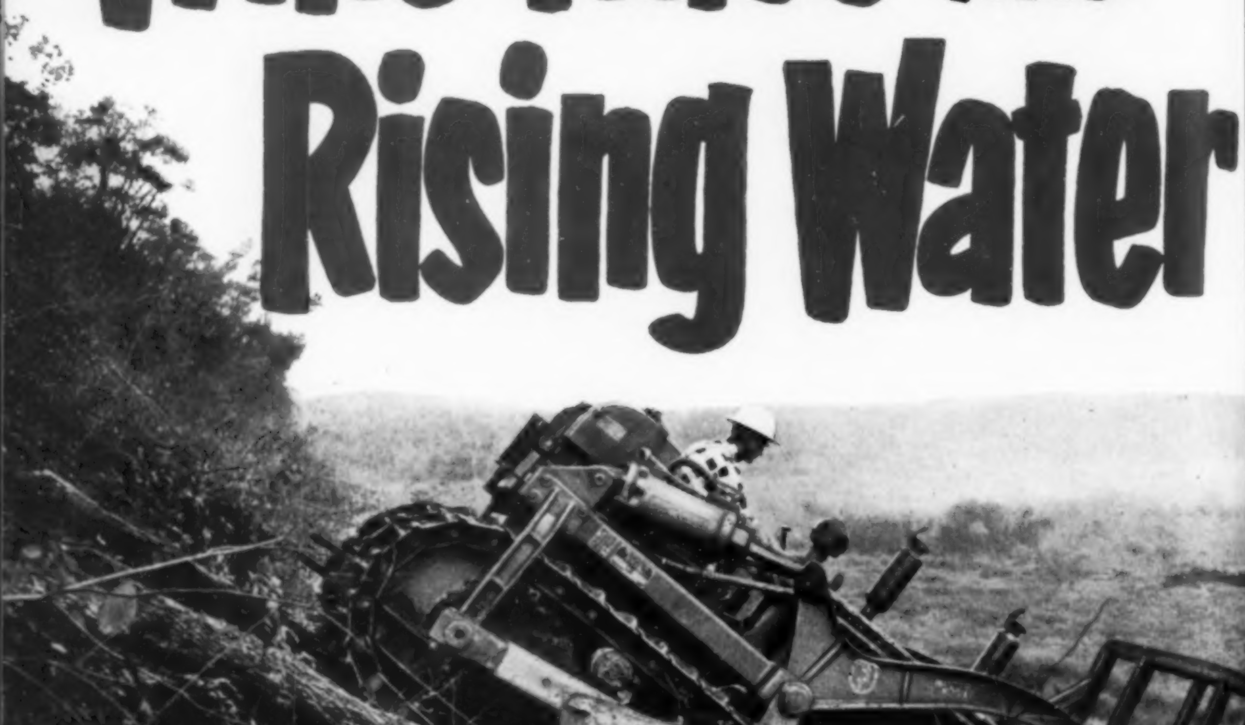
Every type of structure, from large to small, is an Allied job if fabricated structural steel is specified.

Every time you have such a job, be sure to send your plans and specifications to be estimated.

- Clinton Bridge Corporation
- Gage Structural Steel Corporation
- Midland Structural Steel Corporation

Fabricators and erectors of structural steel for highway and railroad bridges; Industrial, office, school, and government buildings; Airport structures; Harbor facilities.

Wins Race with Rising Water



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FROM START TO FINISH

on any grading or rolling job you need GALION'S proved -

ECONOMY OF OPERATION

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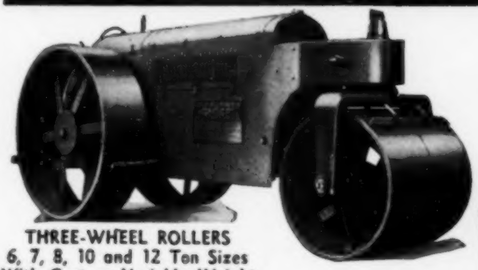
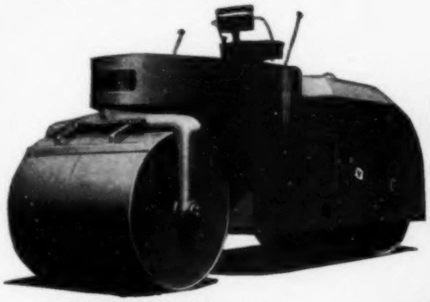
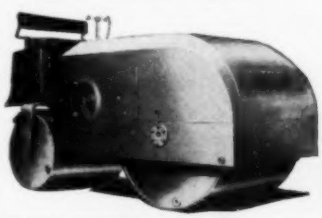


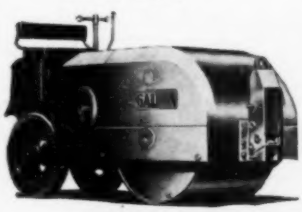
THREE-WHEEL ROLLERS
6, 7, 8, 10 and 12 Ton Sizes
With Cast or Variable Weight
Ballastable Steel Rolls
Gasoline or Diesel Engines



TANDEM ROLLERS
Variable Weight -- 5-8, 8-12, and 10-14 Ton Sizes
Gasoline or Diesel Engines



SMALL TANDEM ROLLERS
Variable Weight -- 3-5 Ton
Gasoline Engine



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Variable Weight - 7100-9765 lbs.
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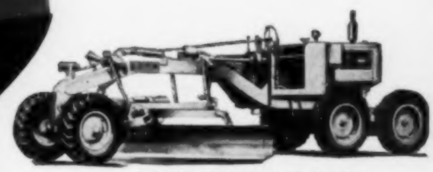
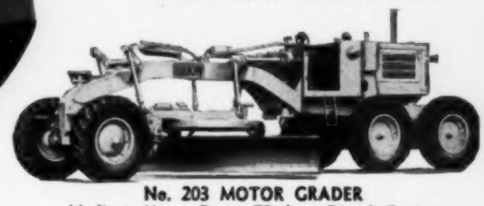
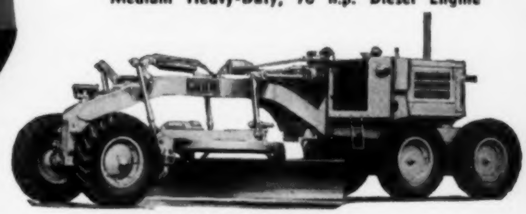


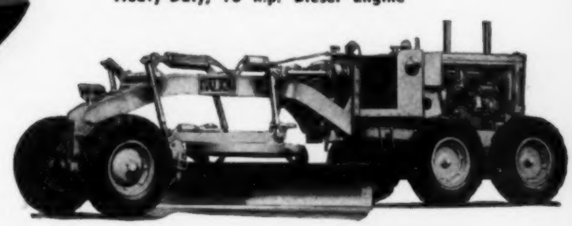
No. 303 MOTOR GRADER
Medium-Duty, 50 h.p. Diesel Engine



No. 203 MOTOR GRADER
Medium Heavy-Duty, 70 h.p. Diesel Engine



No. 104 MOTOR GRADER
Heavy-Duty, 76 h.p. Diesel Engine



No. 118 MOTOR GRADER
Extra Heavy-Duty, 100 h.p. Diesel Engine

Write for literature on type of equipment in which you are interested.

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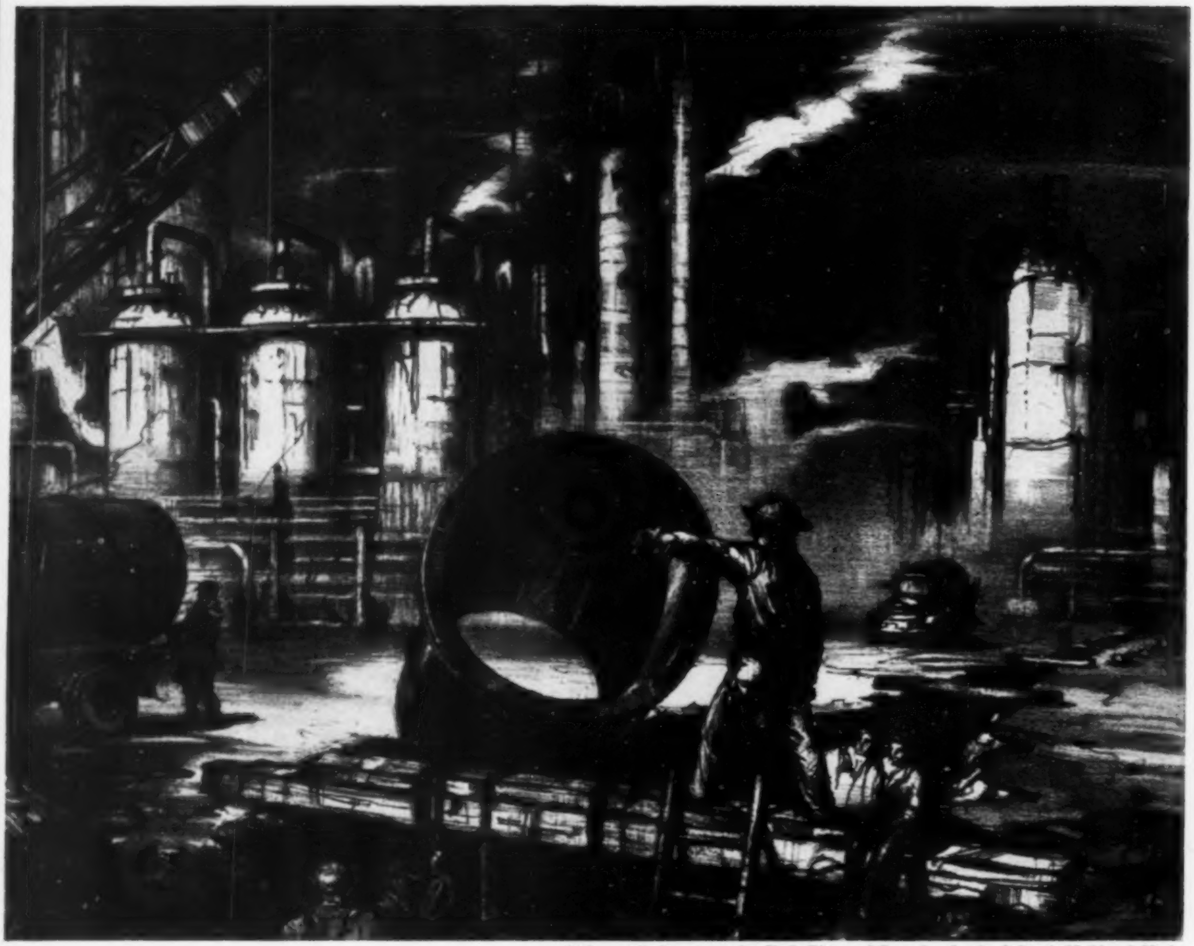
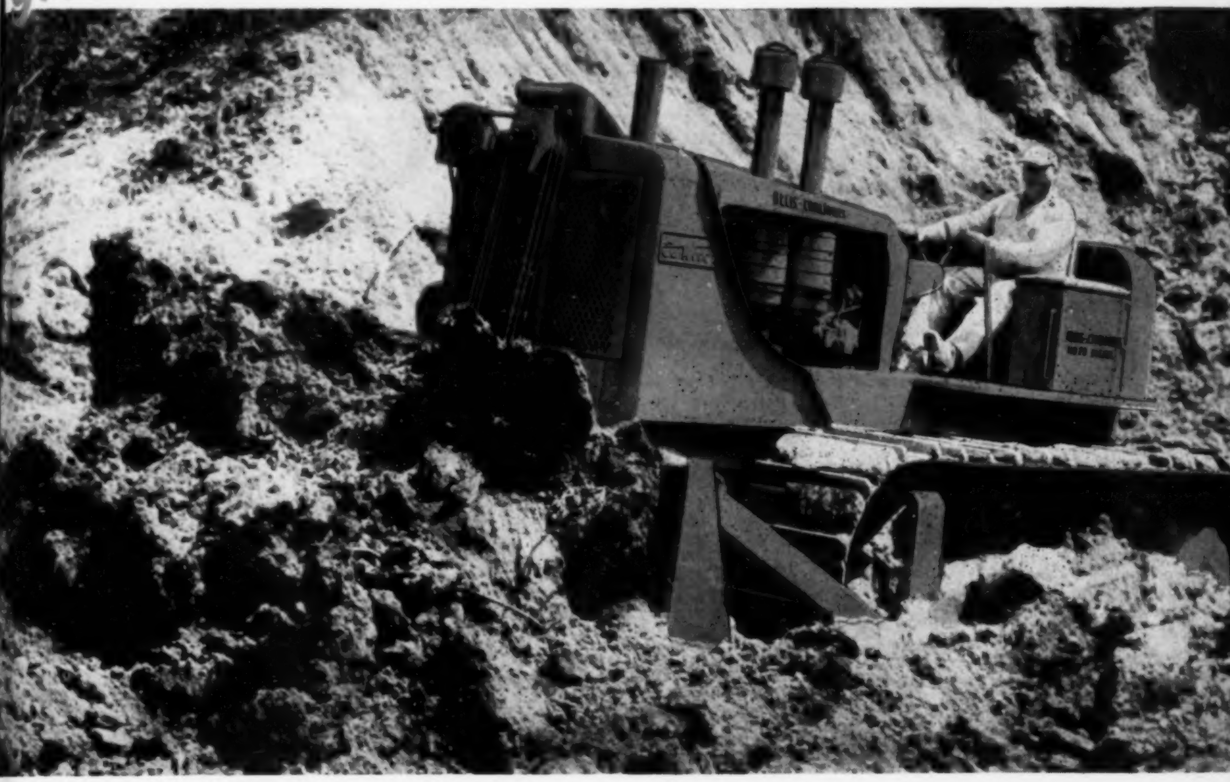
ESTABLISHED 1907 **MOTOR GRADERS · ROLLERS**



Lithographed on stone for U. S. Pipe and Foundry Co. by John A. Noble, A.N.A.

Allis-Chalmers HD-20 Tractor

gives HIGHER OUTPUT with LESS UPKEEP



Exclusive Hydraulic Torque Converter Drive is One BIG Reason Why

The hydraulic torque converter drive, *exclusive* in the Allis-Chalmers HD-20 Tractor, brings you productivity, handling ease and dependability that makes every hour, every day of the season count . . . gives the operator the equivalent of hundreds of gear ratios in two speed ranges . . . automatically selects the proper speed for maximum production.

DOZING With hydraulic torque converter drive you take full advantage of available horsepower . . . you'll roll bigger loads, tackle tougher dozing jobs. Master clutch engages under cushioned protection, yet power is achieved *instantly* with velvet-like smoothness. This means fewer repairs . . . longer life of tractor and auxiliary equipment.

PULLING There's nothing like the HD-20 for sheer productive power. Torque converter actually multiplies torque up to four and one-half times . . . develops tremendous drawbar pull to start the load smoothly, and automatically accelerates to highest speed conditions permit, in either high or low range.

EXCAVATING With full horsepower available even at creeping speed, and shifting virtually eliminated, the operator can concentrate on his front-end shovel completely . . . crowd surely and steadily . . . start and stop with a touch of the throttle.

PUSHING The HD-20 makes smoother contact, automatically matches speed to pushed equipment, maintains steady contact while loading, sends load off to the fill in a higher speed.

Get the full story now from your Allis-Chalmers dealer. See why the HD-20 does more work, more easily, at less cost . . . and why it is worth waiting for.

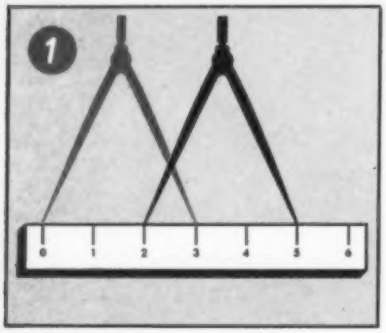
ALLIS-CHALMERS ★

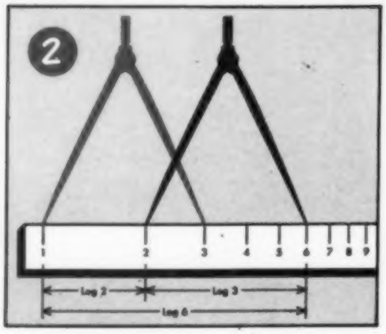
TRACTOR DIVISION · MILWAUKEE 1, U. S. A.

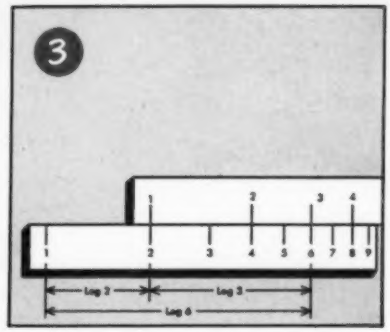
Weight: 41,000 lb.
175 Net hp. at flywheel

ORIGINATOR OF THE TORQUE CONVERTER TRACTOR

Why a Slide Rule Adds



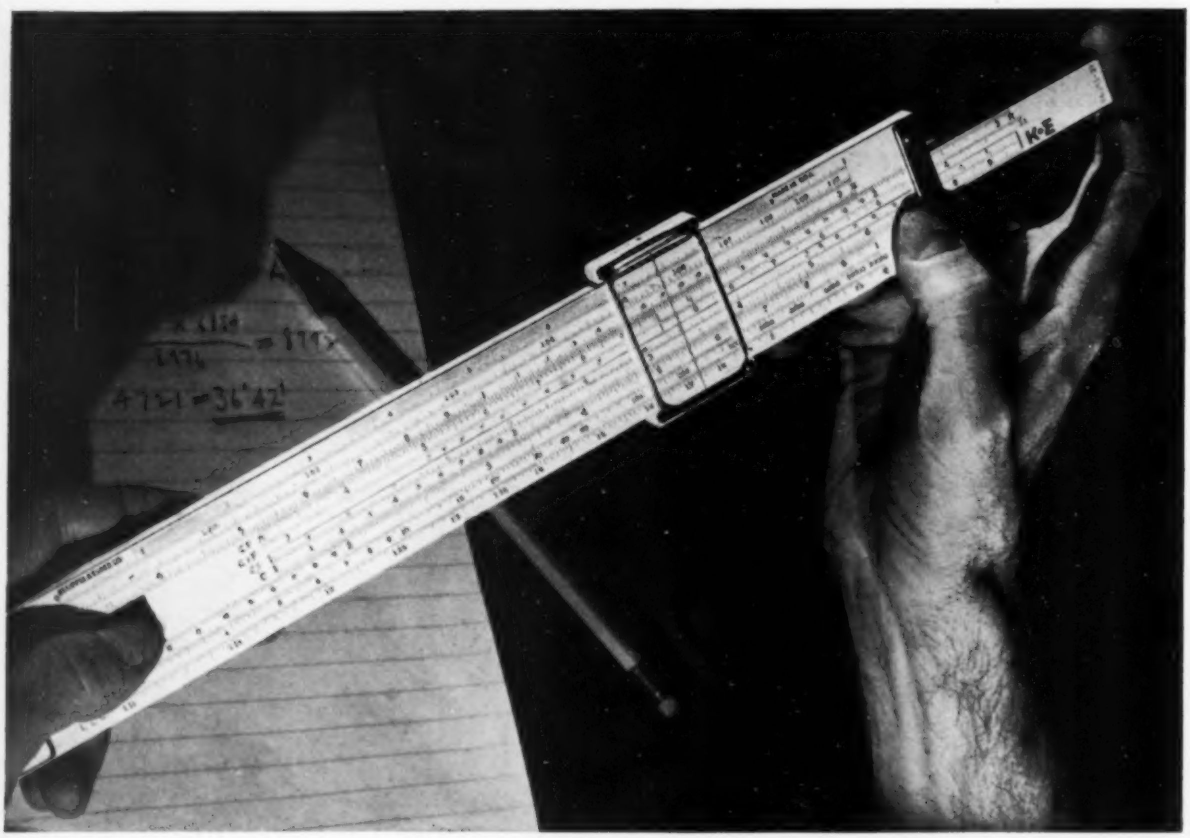




In a mechanical sense, the slide rule merely adds and subtracts quantities. How these simple operations can be performed mechanically may be seen from the illustration above, which shows the addition of 2 and 3 by means of a pair of dividers applied to an ordinary 6-inch rule. Even many electronic calculators work basically on this principle.

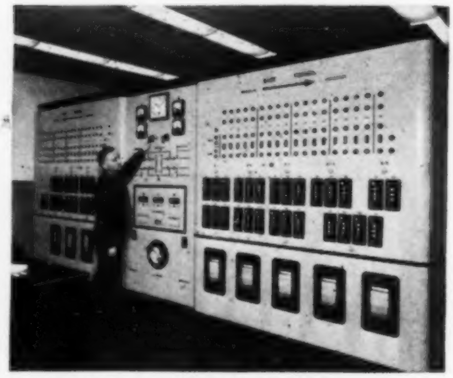
With a different system of calibrations on the scale, if appropriate meanings are assigned to them, more difficult problems may be solved in the same way. An example of this is seen above where a pair of dividers is shown adding 2 and 3 on a logarithmic scale and obtaining the answer 6. Advantage is taken of the fact that the multiplication of numbers may be accomplished by the addition of their logarithms.

A handier method, which begins to approach the usefulness of a slide rule, is to place two similar logarithmic scales together. Seen above is the simple setting in which 2 is shown being multiplied by 3. Observing the illustration it can be seen that the same setting also multiplies 2 by 2 and 4. Without changing the setting, the device shows the corresponding operations in division.



CONTINUOUS-LINE FLUORESCENT LIGHTING—key feature of Brooklyn-Battery electrical system—gives safer, shadowless illumination. Variable light intensity and lower operating costs are other important features.

WELL-LIGHTED APPROACHES lead to tunnel. In daytime, lighting inside the entrance is brighter to provide better transition from sunlight.



CENTRALIZED CONTROL permits one man to operate the complete electrical system—lights, fans, pumps and safety equipment.

Ribbons of light mean safer, lower-cost tunnel operation

Fluorescent lighting, central control, reliable power highlight G-E system at Brooklyn-Battery Tunnel

Now handling 16,000,000 vehicles a year with safety, comfort, and operating economy, New York's Brooklyn-Battery Tunnel provides an excellent example of modern tunnel electrical systems. Designed by engineers of the Triborough Bridge and Tunnel Authority and General Electric, this electrical system was the first to feature economical, variable-intensity fluorescent lighting. Centralized control and a coordinated power distribution system also contribute to operating economy and dependability.

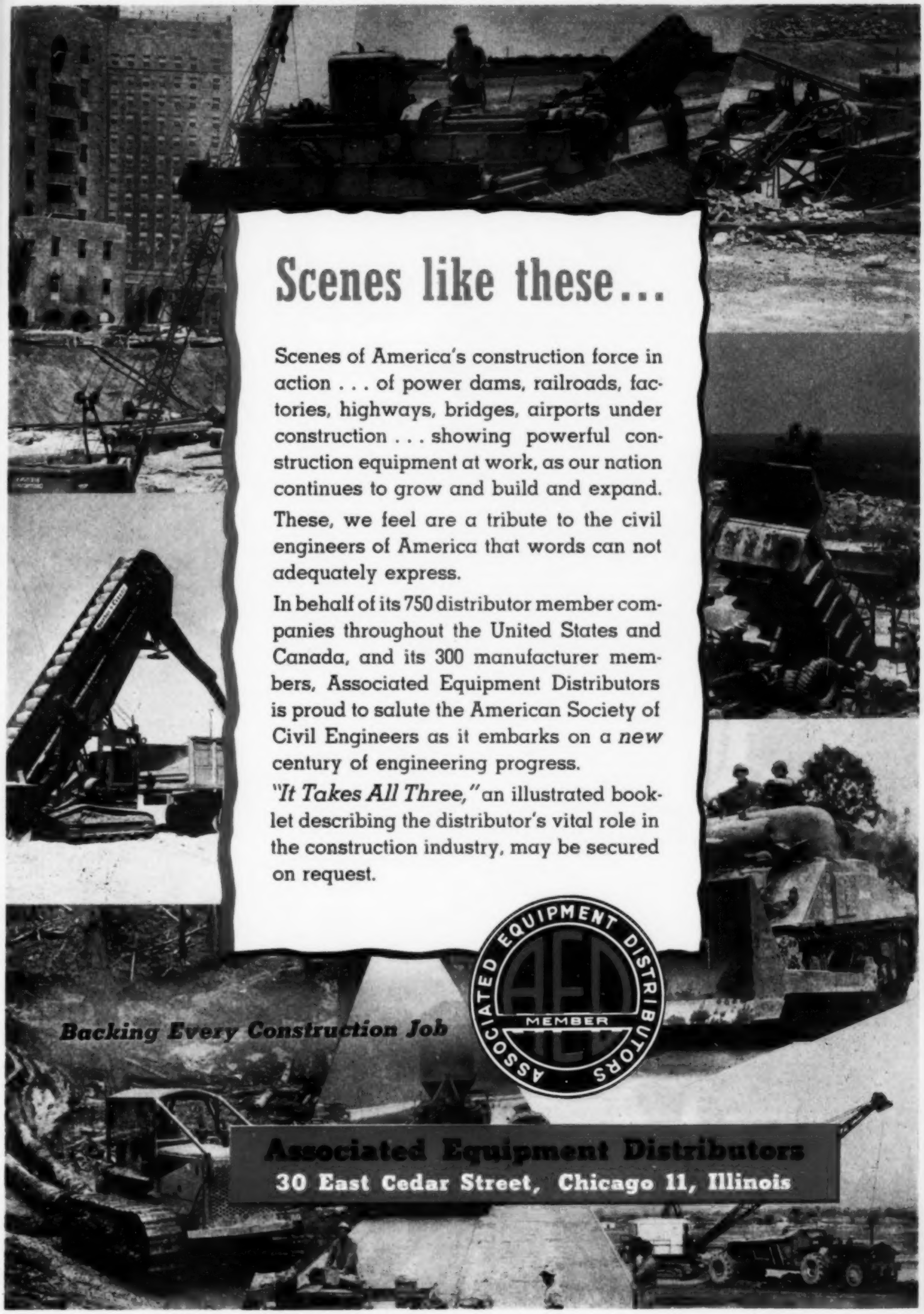
Tunnels are just one of the many types of heavy construction projects on which General Electric is ready to assist your engineers or consultants in electrical system planning. Contact your local G-E Apparatus Sales Office. General Electric Co., Schenectady 5, N. Y.

664-24

RELIABLE POWER—a necessity for tunnels—is provided by G-E metal-clad switchgear. G.E. also builds fan and pump drives for tunnels.

Engineered Electrical Systems for Heavy Construction

GENERAL ELECTRIC


Scenes like these...
Scenes of America's construction force in action . . . of power dams, railroads, factories, highways, bridges, airports under construction . . . showing powerful construction equipment at work, as our nation continues to grow and build and expand.
These, we feel are a tribute to the civil engineers of America that words can not adequately express.
In behalf of its 750 distributor member companies throughout the United States and Canada, and its 300 manufacturer members, Associated Equipment Distributors is proud to salute the American Society of Civil Engineers as it embarks on a *new* century of engineering progress.
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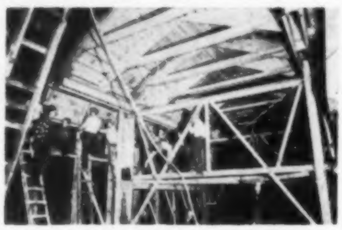
New Day IN THE Old Dominion

Dynamic progress of Tidewater Virginia is illustrated by Norfolk-Portsmouth Bridge-Tunnel, providing direct highway link between the two cities. Left, entrance to new tunnel under Elizabeth River's Southern Branch; above, air view of bridge over Eastern Branch.

Tunnel Building Takes Pinpoint Precision and Heavy Construction Muscle



Elizabeth River Tunnel is tenth of trench type in U. S., fourth of its kind built by Merritt-Chapman & Scott. For 2117' under-water section, 7 double-shelled steel tubes, each about 300' long, 35' 4" diameter, were launched and towed to site. Next step was to concrete 18" inner ring and 22'-wide roadway inside each section, piping concrete through hatchways along top into traveller forms. Then hatchways were concreted and sealed.

Almost awash, tubes are held by derrick slings, as concrete is tremied into place between inner and outer shells, until tubes lose buoyancy. Tube's 9100 tons "in the dry" becomes less than 100 tons under water. Divers bolt sections together, rest of space between inner and outer shells is filled, and section joints sealed, with concrete. Trench is back-filled, bulk-heads holed through, joints faced with concrete—and here's your tunnel!

● Water-coursed topography, which makes Hampton Roads one of the world's great harbors, has long handicapped land transportation. A key project in solving this problem is the Norfolk-Portsmouth Bridge-Tunnel and related facilities, completed at a cost of $23 million.

The trench-type tunnel, 3,315 ft. long, under the Southern Branch of the Elizabeth River is linked with a beautiful, new four-lane bridge, 2,135 ft. long, over the Eastern Branch.

Motorists who now travel swiftly between Norfolk and Portsmouth, instead of waiting for traffic-glutted ferries, are the first to appreciate the engineering and construction know-how which went into this great project.

For one thing, the logistics of a job like this are an achievement of first rank. Clock-like co-ordination meshed men, equipment and materials together as one team. And, team-player that it is, Lone Star delivered 179,233 barrels of cement on the dot of every promise, for the very good reason that . . .

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CIVIL ENGINEERING

SEPTEMBER 1952

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CENTENNIAL OF ENGINEERING, 1852–1952

DEPARTMENTS

CIVIL ENGINEERING

Centennial issue in commemoration of 100th anniversary of ASCE | SEPTEMBER 1952

CARLTON S. PROCTOR, President, ASCE

Moran, Proctor, Mueser & Rutledge, Consulting Engineers, New York, N.Y.

Engineers face major responsibilities in the next hundred years

Of foremost importance to all engineers today is the Centennial of our birthday and its celebration. The founding of ASCE 100 years ago, as the first national engineering association in the Americas, marked the organized distinction between military and civilian engineering practice. Hence, quite properly and logically, we are being joined in our Centennial celebration by our sister societies in the other branches of engineering. This then is the Centennial for the entire profession of engineering in the United States. The success of our Chicago Convocation would have been unattainable without the wholehearted support of our sister societies, particularly the assistance of those members of their governing boards who have accepted membership and duties on the Board of Directors of the Centennial of Engineering 1952, Inc.

The grand culmination of a year of celebration is this Convocation in Chicago, where 61 national and international engineering societies are meeting. Reservations have been made for more than 30,000 engineers and their families. Sixteen foreign nations are represented by their leading engineers. Our activities are filling all of the principal Chicago hotels, and all sizable meeting rooms have been engaged.

The experienced leadership of such men as Maj. Lennox R. Lohr, M. ASCE, President of the Centennial of Engineering and guiding spirit in its exhibits, pageants, and convocation; and Charles F. Kettering, Hon. M. ASCE, Chairman of its Executive Committee, have been invaluable. Major Lohr's qualifications for the directorship of our Centennial, including his creation of the Chicago World's Fair and his leadership in the Chicago Museum of Science and Industry, are without equal. His untiring efforts in directing the Centennial are on a purely *pro bono publico* basis.

The presence of the Chicago Museum of Science and Industry and the proffered assistance of Major Lohr, controlled the selection of Chicago as the Centennial city, as recommended to the Board of Direction of ASCE by our Centennial planning committee. This committee had spent two years of study under the chairmanship of Malcolm Pirnie, a Past President of ASCE. Later Irving V. A. Huie, M. ASCE, became chairman of the executive committee of the Centennial committee. It was this committee that laid the plans and prepared the specifications for this Centennial nearly four years ago.

As for the help of Mr. Kettering, his enthusiasm from the start has been infectious. As chairman of the Executive Committee of the Centennial of Engineering 1952, Inc., he headed up the fund raising efforts. One of his ardent ambitions has been to depict the essential part played by engineers in our country's progress. He agreed with Malcolm Pirnie and his committee that such an epic could be more dynamically portrayed at the great Chicago Museum of Science and Industry, essentially a museum of engineering accomplishment, than at any other place. There he envisaged an unequaled opportunity to demonstrate to the millions who view our exhibits, as well as to the other millions who read of them, the fact that our American progress has resulted from the partnership of the engineer with management, with skilled workmen and risk capital. He has long felt that some such depiction is essential to show that our enormous industrial growth could only have occurred in an atmosphere of cooperation under conditions free from governmental

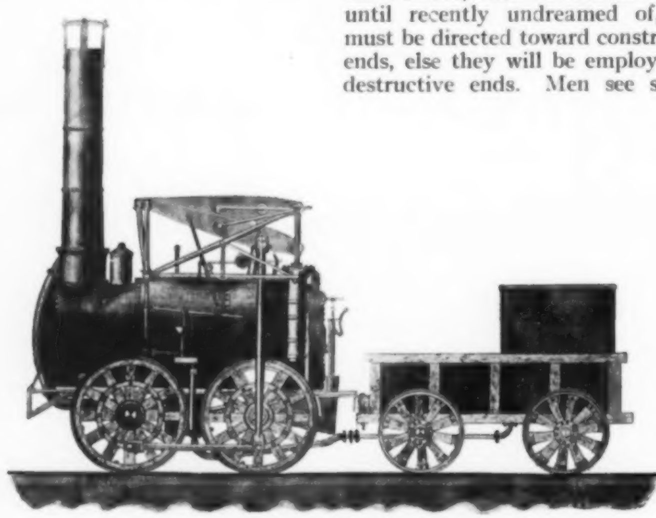
competition, stifling restrictions, and the stagnating influence of socialism.

Now this hundredth year of ours demands of us more than a great celebration and more than a demonstration of past accomplishments. This should be accepted as the year of the full maturity of our profession, the time to take stock of our equipment and facilities to meet the challenge which the engineer faces in the world ahead of us.

On the positive side is a record of proud accomplishment—the vital contribution toward winning the recent World War, so frequently referred to as an engineer's war; the prime influence of engineering in improving our living standards and in developing our tremendous industrial capacity. We have been leaders in the creation of the greatest social structure of all time, so strong that with only 6 percent of the world's population and 7 percent of the world's area, we are supporting the rebuilding and rearmament of the entire Western world.

On the negative side is a world on the brink of another war—a condition tragically induced by the collapse of moral and political leadership, and by man's fear of man's inventions. Our Western world no longer fears the ravages of nature—storm, flood, hunger and cold. Science, technology and engineering have dispelled these fears. But today men fear, more desperately than they have ever feared before, the power and consequences of the inventions of modern science, for the world contains forces, such as nuclear energy, until recently undreamed of, that must be directed toward constructive ends, else they will be employed for destructive ends. Men see science advancing beyond their ability to control its discoveries or to regulate its power for destruction.

The fact that our inventions, innovations and public utility improvements have created a vast amount of non-productive leisure time, beyond the capacity of the average person to culturally employ, has been a subject of only academic interest to us. Despite our record, of which we are justifiably proud, and despite all the glory that will come to our profession at these Chicago celebrations, we just haven't finished our job. We have hidden behind our slide rules when we should have been taking our essential place in the world of public affairs. In perfecting labor-saving devices, mechanization for rapidly raising living standards, and facilities for mass entertainment and travel, we have largely ignored our responsibilities for the social impact, the economic repercussions, and the cultural implementation of our work.



Stourbridge Lion, first full-sized locomotive to be operated in this country, was bought in England in 1829 by Horatio Allen, later to become a president of ASCE (1872). He was working at the time under another engineer who later became a well known member of ASCE—John B. Jervis (Hon. M.ASCE, 1868). The locomotive was used on Delaware and Hudson's canal, incline and railroad project, 1823–1830, directed by Jervis, and characterized as most daring and courageous undertaking of its time attempted under private sponsorship.

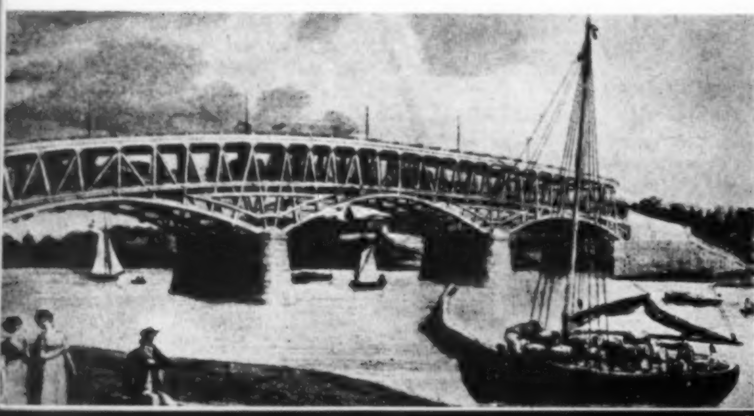
A century

J. K. FINCH, M. ASCE

Dean Emeritus, School of Engineering

Columbia University, New York, N.Y.

The Century of Progress which the American Society of Civil Engineers celebrates this year may also be regarded as marking the fiftieth century in the history of the civil engineering profession. What we know as civil engineering today is but the modern version of an ancient practical art—



Trussed arch across the Schuylkill in Philadelphia, known as the "Permanent Bridge" because it replaced a bridge of boats, was built without knowledge of structural analysis or stresses, by Timothy Palmer in 1805. This bridge exemplifies uncanny intuitive structural sense possessed by early American bridge builders. Forty years later, Squire Whipple (Hon. M. ASCE, 1868) was first to publish a rational method of truss analysis, and thereby inaugurated the modern era of rationalized bridge design.

The most desperate need of today is the reconciliation of science, technology, and engineering to reassure a world in fear of war, and to reestablish man's confidence in the works of man. That job is ours. We the engineers constitute the only catalyzer that can reconcile the opposing elements of destruction on the one hand and of creation on the other, inherent in the engineering world of today. We are supporting an all-out material mobilization when the world needs first an all-out spiritual mobilization.

Six hundred million men belong to our Western civilization, half of them on European shores. The grave question of the day is whether or not this great human group of the West can maintain its unity, strength and leadership. To this great endeavor of preserving and further developing Western standards of civilization, many men will have to devote the best of their character and wisdom, their knowledge and imagination, their enterprise, and above all, their patience and faith. In this effort, we cannot afford the cost of failure. We must pay the price of success.

I believe that the engineer holds a position of large public responsibility and has a unique opportunity in these critical times. His is the obligation devolving from the social impact and economic implications of his work. This opportunity derives from the public's confidence in his analytical judgment. Furthermore a very special stewardship has been entrusted to him. To engineers, more than to any other group, has been entrusted a knowledge of, and the ability and opportunity to employ the divine laws of nature. Actually we create nothing except in compliance with those laws and through their employment. As our understanding of the laws of nature has grown, our capacity for improving man's facilities for enjoyment and fullness of life has increased. Hence we hold a particularly significant responsibility to strengthen man's faith in the eternal.

The new frontier of the engineer is to reestablish leadership by men of emotional and spiritual discipline—to bring men and women of incisive capacity back into public life. Then the 450,000 engineers in this country will approach the dignity of their heritage and assume their responsibilities as constructors of civilization's future, to justify our pride in celebrating a hundred years of engineered progress. Then our Centennial will show more clearly to millions that continued progress demands as a prerequisite the conservation of the American way of life and a rededication to our faith in the dignity of man and his destiny in the eternal plan. Then we may cease to blush at the admonition of Edmund Burke, "The surest way for the forces of evil to prevail is for enough good men to do nothing."

# of progress in civil engineering

A lifetime student and teacher of civil engineering, Dean Finch has recorded for publication in *Proceedings* his observations of the past century of our professional growth in capacity and service toward the economic and material development of America. This summary of his longer paper is illustrated with a few photographs in major fields which reflect the efforts of civil engineers to meet the demands of our growing country. The illustrations are mostly from the author's extensive collection.

the art of construction—which is as old as civilized life itself. From beginnings in Egypt and Mesopotamia at least three thousand years before Christ, the traditions and practices of the ancient master builder have been handed down to us and we carry them forward and add to them as an essential service in the evolution of Western civilization and the democratic way of life.

One would expect, therefore, that American engineering would owe much to importations from abroad. It is commonly assumed, in fact, that the first engineers in the United States had received their training, largely in the military field, abroad, and that we simply appropriated, ready made so to speak, our engineering ideas and methods from earlier European works.

No engineering technique is ever lost. We are constantly working over, revising, improving and adding to past practices and methods. Man has built roads, canals, and bridges for centuries. We did import the steam locomotive from Britain, but American engineering owes relatively little to European techniques and practices. It has grown and developed from pioneer beginnings in a peculiarly American manner to meet peculiarly American needs, wants, and conditions. In part this has been due to the fact that we have been too busy with our own problems to follow with care developments abroad. To a major degree it has been due to the totally different economic and social life that has grown up in America as compared with the older civilizations of Europe.

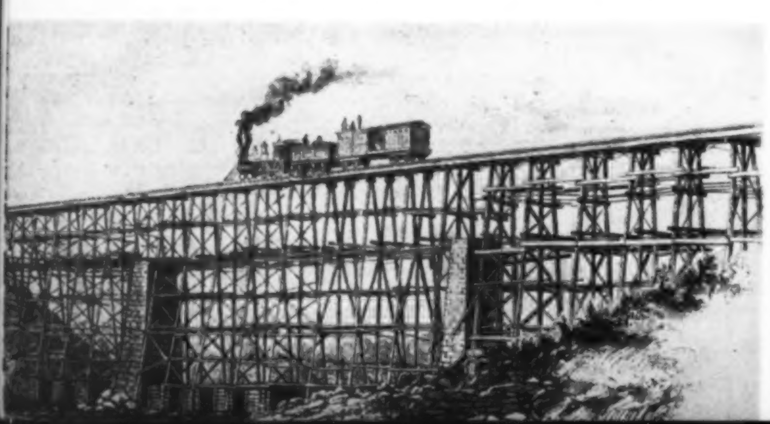
Distinctive Character of American Engineering

American engineering had its beginnings about fifty or sixty years before the founding of the American Society of Civil Engineers in 1852. As early as 1838 a British visitor to our shores, David Stevenson, sensed these fundamental differences which have characterized our engineering development. He noted:

> The zeal with which the Americans undertake, and the rapidity with which they carry out every enterprise, which has the enlargement of their trade for its object, cannot fail to strike all who visit the United States as a characteristic of the nation. English and American engineers are guided by the same principles in designing their works, but the different nature of the materials employed in their

Famous old timber trestle (above) over Genesee River, on Buffalo Branch of Erie Railroad, was built by Silas Seymour in 1851 and destroyed by fire in 1875. Structure, known as Portage Viaduct, was replaced by new pin-connected bridge (below) by George S. Morison (President of ASCE, 1895) in unbelievable time of six weeks—a speed record which has never been equaled.

Civil War military bridge over Potomac Creek was built in 1862 by Herman Haupt in nine days, utilizing soldiers. It consisted, according to President Lincoln, of "nothing but bean poles and cornstalks." During Sherman's March to the Sea, Haupt's assistant, E. C. Smead, built a bridge twice this size in half the time.



construction, and the climate and circumstances of the two countries naturally produce a considerable dissimilarity in the practice of civil engineers in England and America. At first view one is struck with the temporary and apparently unfinished state of many of the American works and is very apt, before inquiry into the subject, to impute to want of ability, what turns out, on investigation, to be a judicious and ingenious arrangement to suit the circumstances of a new country, of which the climate is severe—a country where stone is scarce and wood is plentiful and where manual labor is very expensive. It is vain to look to the American works for the finish which characterizes those of France, or the stability for which those of Britain are famed."

The "plentiful material" was, as he notes, timber. In fact the major problem in the construction of our early canals and railways was to get rid of the forests, trees and stumps that encumbered the routes. Dickens in his *American Notes* of 1842 describes the monotony of travel through such lanes cut in virgin wilderness. Timber was not only plentiful but was well adapted to inexpensive, relatively temporary construction, in a country of meager financial resources, and where the uncertainty of future requirements did not justify a more permanent form of building. As a result, America built in timber rather than in the more solid, permanent, and costly stone which was characteristic of British and Continental practice. There were, therefore, few great American masonry bridges comparable to those abroad, but as a result of his preoccupation with framed construction, the American engineer did initiate the modern era of the truss bridge.

Similarly, as Stevenson wrote, manual labor, that is, skilled labor, was scarce, and even in 1838, as he puts it, "very expensive." This fact exercised an especially strong influence in the pre-machine period in which Stevenson wrote, but it continued to dictate the character of later American design and production even as it does today. Its manifestations are manyfold. This has been the predominating factor in the rise of American power tools, labor-saving machines, and mass production. It has encouraged standardization and has led to the recent development of automatic and semi-automatic equipment. In bridge design it resulted in efforts to minimize the time and cost of construction through the development of plans in which field operations were reduced to a minimum. The typical American pin-

connected truss was born of these same basic conditions.

Railroad Building Dominated Nineteenth Century

But the character and scope of economic needs also strongly color, if indeed they do not dictate, the type of work to which the engineer devotes his effort. The nineteenth century in the United States was preeminently a century in which the dominating problem was transportation, and in this domain the railroad soon became king. Britain's railroad problem was almost completely solved by 1840, that is, in ten or fifteen years. By this date there were more miles of track in the United States than in Britain, but our maximum rate of building was not reached until the decade 1880-1890, when over 70,000 miles were put down. Our maximum railroad mileage, over 250,000 miles—enough to circle the globe ten times—was not attained until 1920. Our tremendous and unparalleled industrial growth has been a twentieth century phenomenon.

The nineteenth century, which had begun with tallow candles, ended with electricity. It came in on horseback and went out in the automobile. It began with the stagecoach and closed with the airplane. It started with an uncertain postal service and ended with the telephone. It ushered in Whitney's interchangeable manufacture; it saw Yankee ingenuity devise "the American system"; it witnessed the development of modern power-driven tools and equipment. All these surely marked great advances in American industry and in engineering services, but by 1900, American manufacturing was still localized in some 14 North Atlantic and North Central states. Agriculture still remained the greatest industry, and even in agriculture maximum employment was not reached until 1910.

The nineteenth century in the United States was thus, from the economic standpoint, primarily a making ready of the way for the unparalleled and unequaled industrial development which was to follow in the twentieth. It was marked by the physical conquest of a continent, by the spread of a people from the Atlantic to the Pacific. The remarkably gifted and able engineer-craftsmen who, in the early days of the Republic, built precedent-making timber bridges to meet purely local needs, gave way, in these hundred years, to the forceful and dynamic civil engineers who joined the East and West with paths of steel.

The engineering profession has never produced more resourceful and determined, more competent directors and leaders of men, than those who, in spite of danger and hardship, led in this conquest of a continent. From the bridging of great rivers to the seeking of the most favorable mountain pass, the civil engineer led his forces in the forward march of the steel rails. It was an age of boisterous, wild and often reckless expansion in which engineering demands made personal qualities of character and leadership of more importance than highly specialized technical understanding. American engineering schools were rapidly developed in the last years of the century but the majority of the civil engineers of the day had earned their title "in the hard way"—through actual service.

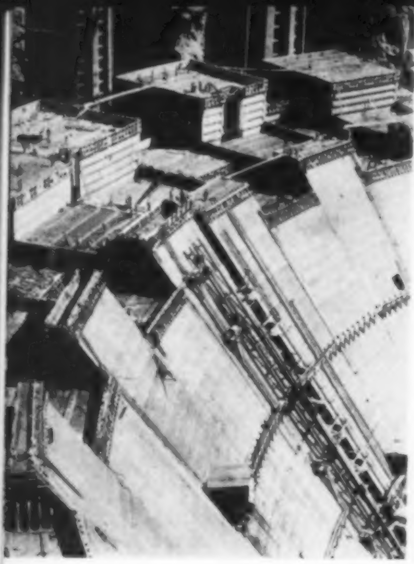
As the century was coming to a close, however, it was becoming apparent that this romantic era was passing and we were facing new conditions and new needs. Our frontiers had been reached, our railroads had been built, our future lay in the further technological development of our material and human resources. It was in 1903 that George S. Morison, a president of our Society, wrote a brief essay, "The New Epoch," forecasting the new era which was to be ushered in with the turn of the century, the new epoch of steam and electrical power, of ever-increasing industrial development, and of new demands challenging the civil engineer to even greater undertakings and accomplishments.

The story of a century of civil engineering progress, therefore, might well be divided into two major periods—the fifty years before the turn of the century and the fifty years since. The first of these two half centuries of civil engineering in the United States was, as we have seen, a pioneering era of timber and wrought-iron construction, dominated largely by railroad building, with some relatively scant attention to urban problems plus a number of unspectacular ventures of cooperative or private enterprises in the irrigation field. Many basic standards and methods of American practice were, it is true, established, notably in bridge construction, but in 1900 the great period of American industrial growth and civil engineering expansion was yet to come.

The second half century was to be marked by the rise of another transportation problem, that of highways, which has created a new field of activity for the civil engineer. Ever increasing urban problems have likewise led to outstanding constructions, while hydraulic works—water supply and power, irrigation and flood control—have resulted in the building of the greatest projects ever undertaken by man. It has been suggested that the nineteenth century marked the heyday of the civil engineer and that the consumer goods engineers have held the leading position since the turn of the century. As a matter of fact, advances in other engineering branches have greatly enlarged the power and scope of civil engineering practice. Increased use of power, mechanization and an ever-greater production have certainly marked these last fifty years, but back of this has been an ever-greater expenditure for the capital goods of plant, trans-

May 10, 1869, witnessed opening of the continent by rail, when Union Pacific and Central Pacific railroads were joined at Promontory, Utah. Maj. Gen. Grenville M. Dodge (Hon. M.ASCE, 1915), chief engineer of Union Pacific, left, shakes hands with Samuel S. Montague, chief engineer of Central Pacific. Theodore D. Judah, a charter member of ASCE, who pioneered construction of Central Pacific over Sierra Nevada, had died in 1863.

Photo Union Pacific



Revolutionary change in technique of dam construction took place in 1913, with building of Kensico Dam in New York City's water supply system. That concrete structure marked point in dam construction where masonry gave way to concrete. Hoover Dam, here shown during construction (1931–1936), by the Six Companies for U.S. Bureau of Recalmation, is arch gravity dam 730 ft high, containing over 3 million cu yd of concrete.

portation and facilities that constitute the domain of the civil engineer and are essential to such productive growth.

Several developments have fundamentally influenced, or even radically changed, the conditions of engineering practice in the last half century. These include the above noted change in the civil engineer's clients from a liaison largely centering in private enterprise to one featuring national, state and municipal agencies, able to carry out works beyond the capacity of private financing. There has also been the great change from the pick-and-shovel era of manual labor and horse-drawn vehicles to the era of mechanized construction. Finally, there has been the replacement at an ever-increasing pace of older empirical methods of design and planning by the more exact, qualitative and effective approaches of engineering science. The search for greater understanding and increased power has been unending.

While it is true that the scope of civil engineering activity depends primarily on economic and social demand, these changes in practice, changes within the profession itself, have to a major degree made possible the bigger and better engineering works demanded by the economic trend.

And where does all this remarkable civil engineering advance and development leave us? Had it been possible to look ahead a hundred years ago when our Society was founded—or even fifty years ago when this new era of unparalleled const)uction opened—we could undoubtedly have avoided some reconstruction and, perhaps, some failures. As a matter of fact, in forecasting future needs, civil engineers probably venture longer-range predictions—as in the great urban water supplies for example—than any other group of engineers. But any effort to forecast future trends in the scope and character of professional practice brings one up against many uncertain and extraneous influences, which make more than an attempt at projected hindsight impossible.

It thus seems certain that man's search to extend the scope and power of engineering activity through a more scientific approach to the problems of design, will continue at an ever increasing pace. Scientific, engineering, and industrial research, directed toward greater understanding and greater control of our material surroundings, is the keynote of the modern search for progress and power.

In engineering, this search must inevitably lead—as it already has led in medicine—to greater specialization. One of the first changes will probably be a greater distinction between the designer and the production or construction type of man. This trend is already under way. The all-around structural engineer of the past, both a capable designer and an able and practical builder, is rapidly passing. The day when a prominent civil engineer such as Kirkwood, second president of ASCE, could turn from railroad to sanitary engineering has already passed.

With this organized specialization and increasing complexity of techniques, the distinction between the professional engineer and the technical assistant is also becoming more strongly marked. There will be few indeed who, lacking specialized education, will rise from the ranks to professional leadership, as often happened in the past.

That there are grave dangers involved in these trends cannot be denied. A complete divorce between design and construction would be fatal, for design is but a means to intelligent and economical construction. Similarly, too great insistence on science and specialization in our educational programs may lead to the development of a narrow engineering mind, incapable of seeing all the many factors that must be considered in planning any great engineering work.

At the same time it seems clear that the construction industry is rapidly becoming a far more highly engineered activity. The planning of construction plant is a major design problem, and the scheduling of operations and direction of forces a major managerial problem. In due course it will be found that much of this new construction technique can be more quickly and effectively taught by the formal processes of the classroom than solely through apprenticeship, as it so largely is today.

There was a period when it seemed that the independent consulting engineer was about to disappear. The cities would, it seemed, have their own engineering forces; the states

Golden Gate suspension bridge, completed across entrance to San Francisco Bay in 1937, and reflecting tremendous demands of the modern highway era, has world's longest span—4,200 ft.

would take over all highway engineering; and the Federal Government would likewise do its own engineering. In the conduct of normal, routine operations and extensions this has undoubtedly become the pattern to be followed. But it is obviously uneconomical, if not impossible, for any governmental organization to maintain specialists in all branches of a profession which is becoming ever more specialized. Furthermore it is wasteful to build up a special staff to undertake new work which is temporary in character or services only needed at infrequent intervals. One would expect, therefore, to find an increase in specialized consulting offices in the future.

Finally, what changes may be expected in the engineer's equipment and construction methods, and what continuing or new demands for civil engineering services may be forthcoming?

With constantly increasing labor costs, it would appear that mechanization in construction must increase although we already seem to have achieved the maximum possible. Unlike the consumer goods industries, the capital goods work of the civil engineer usually requires the production of a custom-made unit; that is, every construction job, since the work is built in place to meet special conditions, involves the production of a new product. It may turn out that in the future we will see far more prefabrication in connection with many minor civil engineering structures or parts.

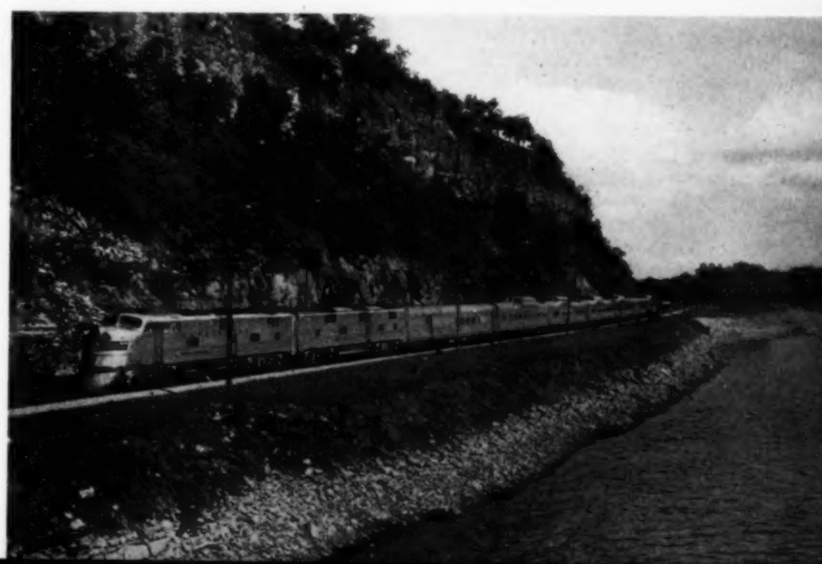
Demand Will Determine Future

But in the end it is demand that will determine the extent of future activities in civil engineering. Growing and expanding economic needs constitute the main determining factor. The needs and wants of our thousands of towns and cities are the backbone of sanitary practice. At the moment the still far-from-solved problems of highway traffic furnish the major activity of our structural engineering firms. The great works of the Federal Government may be spectacular and record breaking but they do not keep the wheels of the profession turning. A strong and healthy economy, a widespread material well-being, are still, as they always have been, the greatest assurance of a continued demand for the services of the civil engineer. Such an economy will call forth the engineer's best efforts and stimulate continued professional development in skill and capacity to serve in the years to come.

Muck sausages pushed their way through doors in shield during driving of Holland Tunnel under Hudson River at New York in 1923. Tunnel was driven under air pressure of 20 psi, about 30 ft below river bottom. Bulk of displaced material was not excavated but simply pushed aside.

Merritt Parkway in Connecticut, near Stamford, exemplifies modern toll road with complete separation of grades and lanes.

Diesel-powered passenger train, pioneered by Chicago, Burlington & Quincy Railroad on Chicago-Denver run, made 1,017-mile run in 1936 in little over 12 hours.



DWIGHT W. WINKELMAN, M. ASCE

President, D. W. Winkelman Co., Inc., Syracuse, N.Y.

Construction . . .

—a growing field for the civil engineer

In 1852, Franklin Pierce was elected President of the United States. I imagine that he rode to the inauguration over an old plank road. There were no superhighways. Baseball was just beginning to become popular in empty lots. There were no huge stadiums. In 1852, the most celebrated building was an imaginary one—*Uncle Tom's Cabin*—published that year, as was also *Ten Nights in a Barroom*.

That was the picture a hundred years and four wars ago.

A century ago, most of the transcontinental railroads crossing the rivers and mountains of the United States were yet unbuilt. The large bridges—the San Francisco Bay Bridge, the George Washington Bridge, and all the others—had not been constructed. The "Big Ditch" (the Panama Canal) had not been dug. There were no New York skyscrapers, no Hoover Dam.

In the one hundred years since 1852, engineers with skill and patience, and contractors with imagination and courage, have changed the picture. That rare combination of qualities, reaching maturity under the free enterprise system, has produced highways, bridges, buildings, railroads, and dams. So, on the one hundreth anniversary of the ASCE, we pay tribute to the productivity of the engineering profession over the past ten decades.

At the same time it is appropriate to review the opportunities ahead for engineers in the construction field. Such opportunities do exist. The United States of 1952 is similar to the one of 1852 in that respect at least. It is still the land of opportunity.

Opportunities in Construction

First of all, it is true that the construction industry, like other industries, has more work than engineers to do it. The 5,500 civil engineers graduated last spring are not enough to carry on the construction program this nation needs. There are likely to be more jobs than engineers for several years to come. As should be expected, the engineer's value has gone up. A joint cooperative committee of the ASCE and the Associated General Contractors of America (AGC) is trying to encourage better salaries for civil engineers. This is a good time for the civil engineer to enter the construction field.

In addition to the usual demands for civil engineers in construction, another consideration is encouraging. Contractors are, and for some time have been, developing new respect for men with an engineering education. The contractor of yesterday was often not an engineer but a building mechanic, with more business sense, courage, and imagination than his fellows. He wanted to be independent. He wanted to pit his ingenuity against other free enterprisers and he often won out by sheer drive.

More than personal courage and initiative are required to keep a construction firm in the arena today. New products and new methods are coming on the market daily. Contractors have learned to rely on their technical aides, the engineers, to keep the firm abreast of the progressive methods and away from the impractical ones.

Many contractors have invited engineers into partnership with them and many are sending their sons (whom they expect to succeed them) through engineering school. The disciplined engineering mind has a contribution to make to the fierce, highly competitive construction industry.

The skilled training of the engineer has won the respect of the general contractor. Contractors not only have accepted the technical guidance of the engineer, but would go further. Most contractors want their engineers to be able to shoulder other responsibilities. They would like to see these engineers absorb some of their own abilities to manage men and machines, schedule the job, and weigh costs. They want their engineers to be more than draftsmen and designers. They want them to move into more responsible jobs. In that attitude lies new promise for young civil engineers.

One contractor has said, "It is largely the ability to handle executive, managerial, and general business matters in addition to having technical competence that distinguishes the professional man from the technician or craftsman."

Today, engineers are assuming those greater responsibilities. The statistics of the Society bear this out. From 1933 to 1945 the Construction Division membership practically doubled, increasing from 2,700 to about 5,300 members. From 1945 to 1952, the Division membership again more than doubled, reaching a total of more than 12,000.

For purposes of comparison, it is of interest to give some figures for general Society membership. From 1933 to 1945 the Society membership increased from some 15,250 members to a total of 20,400, an increase of about 33 percent. From 1945 to 1951 it rose from 20,400 to 31,800, another increase of 55 percent. In startling contrast to the increase in the general Society membership is the increase in the number of members of the Society engaged in contracting. From 1933 to 1945 this increase was only about 20 percent, whereas from 1945 to 1951, the number of ASCE members engaged in contracting increased by 320 percent, and now totals about 6,000.

In addition, the number of contractor-engineers who have been ac-

tive in the Construction Division through the years should be noted. Among them are: W. J. Barney, J. P. H. Perry, Arthur S. Bent, A. P. Greensfelder, A. E. Horst, S. D. Bechtel, John W. Cowper, Charles H. Tompkins, Lester C. Rogers, and many others. These men are engineers who became leaders in the contracting business and most of them have been officers of AGC. It should be emphasized that the trend for engineers to rise into commanding positions in the construction industry reveals that there are broadening horizons for the civil engineer.

Educators Cooperate

Until recently, engineering education has lagged in the task of preparing young civil engineers for the construction field and the contracting business. In 1922, thirty years ago, only five courses in construction were being offered in engineering schools. Even ten years ago, there were only 72 such classes, although there were 45 different schools. At that time A. J. Ackerman, M. ASCE, then chief of engineering for Dravo Corporation, wrote that the schools were offering only "a smattering" of construction engineering. Such a situation existed even as late as 1942, although it has been estimated that 44 percent of all civil engineers ultimately become engaged in some phase of construction.

However, educators now are recognizing that the construction industry is a field of opportunity for engineers. There seems to be more emphasis on construction courses in technical schools. More courses are being offered in building construction, methods and equipment, estimating and costs, contracting, labor relations, health and safety measures, and job management. Even designing engineers are being encouraged to become cost conscious. Recently L. E. Grinter, M. ASCE, when he was vice-president of the Illinois Institute of Technology in Chicago, wrote of this tendency:

> Believing as we do that only *economical* design is good design, we also emphasize costs to a greater extent than any other college except the College of Business.

It might be thought that the Institute was training general contractors!

Contractors Cooperate

The construction industry is taking more than a passive interest in this trend. A few years ago, the Carolinas Branch of the AGC raised a $100,000 endowment fund so that the North Carolina State College of Agriculture and Engineering in Raleigh could institute a curriculum leading to a degree in construction. In many communities, other AGC chapters are collaborating with engineering schools to initiate construction classes, and several chapters of AGC offer scholarships to promising engineers for additional study in construction.

These are good moves and the industry will benefit from them.

There is another even more authentic reason to believe that the future for civil engineers in construction is bright—because the future for construction itself is bright. Just before World War I, construction volume in the United States was about 5 billion dollars. Last year, it topped 39 billion dollars to become the nation's largest single industry.

The ASCE was born in an age of virgin opportunities. A whole country lay before it relatively undeveloped. In 1952 contractors envision a fertile future for their industry. The need for construction today dwarfs the need of 1852. The United States is now highly developed, but it is going to be fantastically great tomorrow.

There is a tremendous job ahead for builders. According to the U. S. Public Health Service, at least 7,000 new waste treatment plants—more than one billion dollars worth of work—are necessary. According to the U.S. Office of Education, 600,000 classrooms—about 15 billion dollars worth of work—are required. According to the Corps of Engineers and the Bureau of Reclamation, at least 80 new dams under the Pick-Sloan Plan alone—about $4\frac{1}{2}$ billion dollars worth of work—will be called for. According to President Harry S. Truman, atomic energy installations which would cost about 5 billion dollars are needed. According to the Defense Electric Power Administration, power plants costing 12 billion dollars will have to be built in the next three years.

Bright Future for Construction

It is difficult to predict the billions that will be spent by private industry for new plants, by states and cities for public works, and by the armed forces for a continuing defense program. No wonder the Bureau of Labor Statistics in its recent volume on employment opportunities calls the occupational outlook in the construction industry "decidedly good!"

It would be unfair to survey the long-range future of construction without recognizing the disconcerting possibilities of the next few years. Peacetime construction has already been deferred temporarily, but only because a bigger job—the defense buildup—is necessary. There is no doubt that civil engineers distinguished themselves during World War II and can be depended on to repeat, if necessary, what has since become known as an American miracle.

Speaking of that phase of the last war effort, a few years ago, Chief of Engineers Gen. Eugene Reybold, M. ASCE, reported:

> By the war's end, it was evident that American construction capacity was the one factor of American strength which our enemies most consistently underestimated. It was the one element of our strength for which they had no basis for comparison. They had seen nothing like it.

If the United States faces such grave danger again, the need for civil engineers to repeat construction miracles will be greater than ever. Essential at all times, engineers will be doubly so then.

In addition to the practical opportunities already mentioned, there are other, intangible rewards, little spoken of but always recognized. More than weekly checks and professional advancement are in store here. There is the satisfaction of seeing ambitious plans turned into ribbons of concrete highway, tall buildings, solid dams, and long, beautiful bridges. In these achievements the engineer finds himself in a key position. He sees the rough, undeveloped site and the attractive finished product and knows that he has been instrumental in that transformation. He finds new challenge in each project and discovers the joy of cracking hard problems.

It is to these rewards that the construction industry invites the civil engineer.

(This article is based on Mr. Winkelman's address before a joint session of the ASCE Construction Division and the Associated General Contractors of America, Inc., at the Centennial Convention in Chicago.)

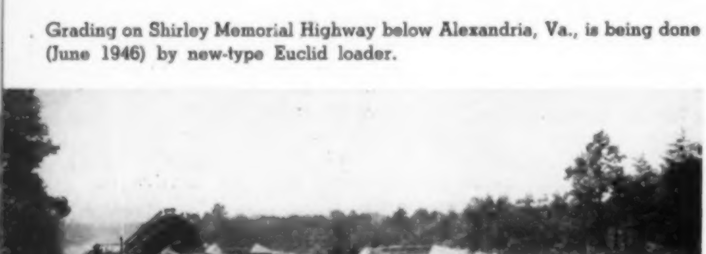
World's best highway sy

U. S. Bureau of Public Roads Photos

On earth-moving job near Lewisville, Tex., modern Caterpillar carrying scraper averages 22 to 25 cu yd per trip on 6,500-ft haul from borrow pit to fill.

Compaction is accomplished on Shirley Memorial Highway below Alexandria, Va., with big Le Tourneau sheepsfoot rollers (June 1946).

Grading on Shirley Memorial Highway below Alexandria, Va., is being done (June 1946) by new-type Euclid loader.



Development and skillful use of modern construction equipment has permitted the United States to build by economical methods the world's best system of highways. The extensive use of the automobile by Americans in their daily lives and the great area of this country have created the tremendous demand for improved roads.

This need has been met by much pioneer work on the planning, design, and construction of highways. No small part of this pioneer effort has been devoted to the development of more satisfactory construction machinery and the more effective use of this equipment. The continuous upward spiral of wages and the continuous increase in highway engineering standards and specifications have demanded increased mechanization. As a result of these several factors, America's highway contractors are now using equipment and methods that are attracting worldwide attention.

World Records Established

Only through mechanization could such outstanding accomplishments as the world record for the continuous placing of concrete have been accomplished. This record was made when 26,700 cu yd of concrete for the seal of the east anchor pier of the new Delaware Memorial Bridge was placed in 7.4 days. Another outstanding record was the construction in 1950, by one paving crew, of 4,700 lin ft of 11-ft-wide concrete pavement in one day, and the construction by a number of contractors of the 118-mile 255-million-dollar New Jersey Turnpike in two years. The New Jersey Turn-

system produced by modern equipment

A. N. CARTER, A.M., ASCE, Manager, Highway Division, Associated General Contractors of America, Inc., Washington, D.C.

pike included 52,000,000 cu yd of earthwork, more than 260 structures (of which 5 were major bridges), and 7,000,000 sq yd of pavement.

Because these accomplishments have been made possible by the many recent advances in highway construction equipment, it is appropriate to review the development of such equipment and its influence on road-building methods. The development of today's economical construction methods cannot be credited to any one group; rather it is the result of the combined efforts and cooperation of the engineering profession, public officials, the manufacturing industry, equipment distributors, producers of materials, labor, and the contracting profession.

This joint effort has paid big dividends and without it, the cost of highways would be prohibitive. The ingenuity and cooperation of all segments of the highway industry have been necessary to provide the tremendous mileage of American highways with the limited funds that have been available.

The changes in road construction equipment in the past 50 years have been revolutionary. Turning back the pages of history, we find the following highlights. One of the first machines built especially for highway construction was the roller to aid in compaction. Some rolling equipment may have been used in constructing the Roman roads, but the first major practical application of rolling equipment appears to have been made by French engineers in 1829. The first recorded application in England was soon after.

In 1865 a steam roller was designed and built by Gellerat & Co. of Paris, France. The first steam-powered three-wheeled roller manufactured in the United States was manufactured in the 1880's by the Harrisburg Foundry and Machine Co., Harrisburg, Pa. Tandem rollers were developed about the same time. In 1908 the Kelly-Springfield Co., Springfield, Ohio, designed and built the first gasoline-powered tandem roller produced in the United States. Today we take for granted the excellent American-made rollers, which feature four speeds forward and four in reverse, high-speed transmissions, low-pressure hydraulic steering systems, all-welded steel frames, and high-speed heavy-duty engines, either gasoline or diesel.

Self-Loading Cart Patented in 1850

A U.S. patent on a self-loading cart was issued as early as 1850, and U. S. patents were granted for wheeled scrapers in 1884. The earliest type of carrying scraper did not appear until after 1900. About 1924 the self-propelled scraper was placed in service. A U. S. patent for a road grader was issued as early as 1855. This was to A. Kimball. In 1863 another was issued to C. W. Pisgah of Ohio.

What may have been the first factory-produced American blade grader was constructed in 1879 by the Western Wheeled Scraper Co., of Fairfield, Iowa. A curved blade was suspended beneath a conventional wagon box and large hand levers were employed to raise and lower the blade.

A steel-frame, reversible-blade grader was manufactured in 1888 by the F. C. Austin Co., Chicago, Ill. However, not until 1922 or perhaps shortly before, were rubber tires used on graders, and in 1924 the self-powered grader appeared. In 1927 the first dual-drive power grader was produced at Harvey, Ill. Roughly ten years later, the all-wheel drive and all-wheel-steer power grader was introduced.

One of the first bulldozer blade attachments in this country was used at about the turn of the century on a project of Foley Bros., pioneer railroad builders. This firm attached an improvised bulldozer blade to a steam-traction engine. In 1915 the Western Wheeled Scraper Co. was manufacturing what was perhaps the first factory-built bulldozer. It was operated with the power from two horses or mules.

More than 100 years ago the first power shovel was built, a crude rig powered by steam, in tremendous contrast to today's shovels, which include a Marion crawler-mounted unit handling a 50-cu yd bucket.

The earliest American self-laying track-type tractors appeared soon after 1900. One of the first was constructed at Stockton, Calif., about 1905. That machine moved in a manner suggesting a crawling caterpillar; hence the name "caterpillar" tractor, which was registered as a trademark and has become world famous.

Thus, we see that this century was well advanced before the appearance of what we call modern equipment. But then things began to happen fast and American equipment was revolutionized. In the twenties the use of horses and mules for power was replaced by the gasoline engine.

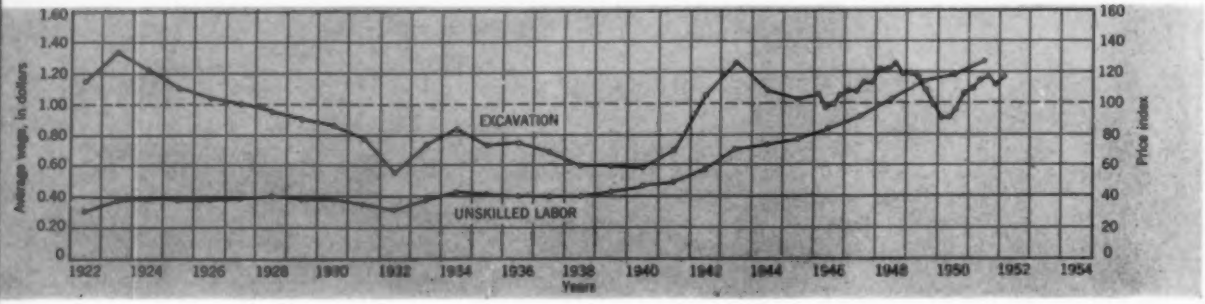


FIG. 1. Index for common highway excavation is compared with average unskilled wage rate.

In the early thirties construction costs were further reduced by substituting diesel power for gasoline. In the late thirties costs were lowered still more by the use of rubber tires, the development of rigs of greater speed, the improvement in ease and safety of operation, and the production of units of greater capacity.

As more types of equipment were developed and placed in service, standardization became a problem. The Associated General Contractors of America, in cooperation with other groups, has worked hard on this job. Much of the early work was aimed at standardization of concrete mixers. The first standards officially sponsored by the AGC were published in 1924. Before that time, the determination of size was left to the manufacturer. It is recorded that there were some 20 different sizes of building mixers and 10 different sizes of paving mixers. The cost of producing such a line is obvious, and the promotional efforts of the manufacturer were often more confusing than instructive. Since then there have been 20 revisions of these standards. The spacing of sizes is so designed that one size takes up where another leaves off, and there are no needless intermediate sizes. The manufacturer must guarantee a certain minimum capacity under standard rating conditions.

Similar standardization has since been applied to numerous other types of contractor's equipment, such as self-priming centrifugal pumps, shovels, cranes, truck mixers, agitator trucks, and air compressors.

Equipment Improvements Still Needed

Despite the many important improvements made in construction equipment in recent years, contractors are seeking additional progress. Advancements they would like to see include:

- More flexible equipment
- More refinements on equipment
- Higher speed in machines
- Equipment that is easier on the operator
- Units that can produce for longer periods without shutdowns for repair or maintenance, other than routine maintenance
- Machines of lighter weight
- Units requiring fewer operators, in view of the high wages paid today's skilled and unskilled workers on highway construction
- Greater ease in maintenance and repair of equipment
- Greater standardization of repair parts and of the actual equipment itself

Mechanization, combined with the resourcefulness of engineers, equipment manufacturers and contractors and their zeal to complete each project more quickly and at reduced costs has resulted in development of the world's greatest highway system. The highway engineering profession is to be congratulated on the spirit with which it has tried new materials, improved designs and introduced scientific methods. Great credit also is due the contracting industry. A few decades ago construction methods were crude and simple, and the premium for good management was not too high.

With today's huge investment in equipment, high wage rates for all crafts, and high standards of performance set by the engineers in charge, contracting management demands top-caliber superintendents and project managers. Without such people the contractor is soon out of business. The low cost of highway construction over the years proves that both engineers and contractors have met the challenge successfully.

When engineers of the U. S. Bureau of Public Roads were asked to comment on the influence of the use of equipment on highway construction costs, as revealed by the Bureau's index for excavation, they reported as follows:

> Since the Bureau's index was started we have made a continuous study of the con-

Below: This horse-drawn elevating grader was watched at work by sidewalk superintendents in Davenport, Iowa, about 1900.

U. S. Bureau of Public Roads Photos

tractors' cost as determined by wage rates and the price of equipment and materials, plus other factors. Over the years there has been a continued rise in labor rates, in the price of equipment and materials, and in the contractors' overhead. If these increases had not been offset by the development and skillful use of modern construction equipment, road excavation costs today would be about three times as great as they actually are.

This is borne out by the price trend for common excavation. The Bureau of Public Roads index, started in 1922, is based on the average of all federal-aid projects awarded by all the state highway departments. The base period for the BPR index is the five years 1925 through 1929. The composite mile is assumed to require 17,491 cu yd of excavation, 3,726 cu yd of paving, 16,000 lb of structural steel, and 68 cu yd of structural concrete.

The Bureau's index shows that in the 18-year period 1922 to 1940 common excavation costs were reduced continuously, as shown by the accompanying graph, Fig. 1. In the early 1940's construction prices had to rise as a result of the impact of World War II, greatly increased wage rates, higher prices for materials, shortage of equipment, and decreased efficiency of labor. However, the national average for common excavation for the calendar year 1951 is lower than that for 1923, the second year of the Bureau's index. The index figure for the calendar year 1923 was 133.3, and that for the calendar year 1951 was 111.3, or 15.2 percent lower.

The continued decrease in the cost of common excavation was obtained despite the continued increase of refinements in specifications and engineering designs.

In contrast to the reduction of the cost of common excavation, wage rates on road work climbed continuously during the same years. Table I, which was supplied by the BPR, gives the average hourly wage rates for unskilled labor on all federal-aid projects. The national average, which was $0.38 for 1923, in 1951 had skyrocketed to $1.27, an increase of 243 percent. Moreover, today skilled labor is used on many operations on which unskilled labor was employed in the past. The variation in the highway excavation index as compared with average unskilled wage rate also is shown in Fig. 1.

Unfortunately, data regarding wage rates for skilled workers are available for only the past five years. The rates for these years, as taken from BPR records, are included in Table I. The table shows that, while the skilled-labor rate rose 28 percent in the last five years, unskilled rates jumped almost 40 percent.

TABLE I.

Average Wage Rates per Hour on Federal-Aid Highways

Calendar Year	Hourly Rate	Calendar Year	Hourly Rate
For Skilled Labor*		**For Unskilled Labor** *(Continued)*	
1947	$1.68	1935	$0.41
1948	1.82	1936	0.40
1949	1.98	1937	0.40
1950	2.03	1938	0.40
1951	2.25	1939	0.42
For Unskilled Labor		1940	0.46
1922	$0.32	1941	0.48
1923	0.38	1942	0.58
1924	0.39	1943	0.71
1925	0.38	1944	0.74
1926	0.38	1945	0.78
1927	0.39	1946	0.83
1928	0.40	1947	0.91
1929	0.39	1948	1.02
1930	0.39	1949	1.13
1931	0.36	1950	1.19
1932	0.32	1951	1.27
1933	0.38		
1934	0.42		

* Data available for five years only.

Today, America's highways are woefully inadequate for the country's road construction needs, placed at between 40 and 60 billions of dollars. Indications are that the American highway user is willing to invest more for highway improvements, as proved by the fact that additional financing for road construction at the state level has been secured in more than 30 states since 1945. The outlook for an increased road program is bright, but close cooperation of all groups interested in road construction will be required if the job is to be accomplished effectively.

America's highway contractors, by working through their state organizations and the national office of AGC, are continually striving to develop more economical construction procedures and practices. Much of this work is being accomplished through cooperative committees set up jointly with other organizations.

Cooperation Pays Dividends

For example, much of the work of the Joint Committee of the American Society of Civil Engineers and the AGC pertains to highway construction. The ASCE representatives include a nationally known highway consulting engineer. The AGC members include two highway contractors both of whom have served as national presidents of AGC, plus two members from firms that do extensive highway work.

The work of the ASCE-AGC Joint Cooperative Committee has included projects aimed at securing:

1. Better salaries for engineers, particularly those employed by state highway departments and other highway agencies.
2. Better training for student engineers through improved courses dealing with construction and summer employ-

Below: Early horse-drawn blade graders were of light weight. Curved blade was suspended beneath conventional wagon box and was raised and lowered by large hand levers. Type shown was used at Geneva, N.Y., in 1898. Self-powered grader appeared in 1924. Below: Residents of Jackson, Tenn., saw this crew in action about 1903, using early distributor for bituminous material.

U. S. Bureau of Public Roads Photos

U. S. Bureau of Public Roads Photo

Horse-drawn, end dump wagons of this type were being used as early as 1896. This rig was employed on "object-lesson project" of what is now U. S. Bureau of Public Roads at Geneva, N.Y.

ment by contractors on construction projects.

3. Improved specifications and planning for all types of construction, including highway work.

4. Allotment by defense agencies of sufficient supplies for construction programs of major importance to the national economy and to national defense, particularly highway transportation.

The AGC also works closely with highway engineers throughout the country to secure more economical construction practices and methods. This program is spearheaded by the Joint Cooperative Committee organized in 1921 between the American Association of State Highway Officials and AGC. Some projects of this group are similar to those with the ASCE, but in addition include continued work to secure more satisfactory public relations programs in connection with highway operations. Also, considerable work has been done to obtain more uniformity in state regulations regarding the transportation from job to job of large road-building machines. When increased uniformity is obtained, benefits to the contractor will follow, and he in turn will be able to submit lower bids, and the state departments to secure more economical prices.

Contractors are cooperating with highway departments on a program to obtain constitutional amendments to protect highway user funds for highway improvements. Such amendments are still needed in 25 states.

The AGC works closely with the U. S. Bureau of Public Roads and the Highway Research Board in an attempt to develop better and more satisfactory construction procedures and practices.

Joint cooperative committees between the AGC and both the Associated Equipment Distributors and the Construction Industry Manufacturers Association have been in operation for a few years. Cooperation with AED and CIMA is aimed at securing improved equipment for all types of construction operations and in making most effective use of that now available. Much has been done to standardize procedures for purchase and distribution of replacement parts, to fix the rated capacities of different equipment, and to pass along to manufacturers the suggestions of contractors on how the design of various machines might be improved. In the work of all the joint cooperative committees, the aim has been to get the maximum benefit from every construction dollar.

The highway contractor's investment in construction equipment is large. Commissioner Thomas H. MacDonald of the Bureau of Public Roads not long ago stated in a public address that studies by his staff showed that generally the contractor's investment in equipment on a road job was about 90 percent of the amount of the contract. In other words, on a $100,000 job he might be using $90,000 worth of equipment.

Because of the contractor's large investment in equipment, a few suggestions are listed [in box below] as to steps that might be taken by highway engineers and officials to permit contractors to operate more effectively and thereby submit lower bids to awarding agencies.

To conclude, a tremendous challenge lies ahead to meet America's highway needs. It is the belief of the AGC that the civil engineering profession and the construction industry, through cooperative effort, will meet that challenge in a commendable manner and thereby make America a stronger nation and a better country in which to live.

In the preparation of this paper many sources were used for background data. These include *Engineering News-Record*, *The Constructor*, *The Virginia Road Builder*, *Excavating Engineer*, *Roads and Streets*, CIVIL ENGINEERING, and other publications. Numerous texts were also reviewed and *Tools of the Earthmover—Yesterday and Today*, by J. L. Allhands (Sam Houston College Press), proved especially helpful. Also, much assistance was secured from the Bureau of Public Roads. Sincere thanks are extended to all those that so kindly gave their assistance.

(This article was prepared from the paper by Mr. Carter presented at the joint session of the Construction and Highway Divisions, presided over by DeWitt C. Greer, M. ASCE, at the Centennial Convention in Chicago.)

Methods to Speed Construction and Lower Costs

1. Permit the contractor free use of new types of equipment.

2. Be sure land is available and the job ready for the contractor to move in and start work when bids are opened.

3. Use local construction materials to a maximum. (This will also reduce the cost of materials.)

4. Prepare designs that will permit maximum use of the splendid construction equipment now available.

5. Cut hand labor to a minimum.

6. Award programs in contracts of various sizes.

7. Work for greater standardization of design so as to obtain savings, for example, through the use of the same type of bridge forms in neighboring states.

8. Use specifications without revision for as long a period as feasible and practicable; that is, do not change the general specifications each year, and when they are revised, obtain the contractor's suggestions by contacting his state organization.

9. Make the specifications of neighboring states as uniform as possible. Contractors see no need for one state to specify that all batches of concrete be mixed for at least two minutes and a nearby state to specify a one-minute minimum mixing period.

10. Utilize to the fullest extent each year's construction season so as to permit maximum use of the contractor's equipment and personnel, and thereby get better prices.

11. Endeavor to set up a balanced construction program. For example, if a highway department schedules a large volume of black-top work for one year and none the next, it will be difficult for the construction industry to keep in step, and higher prices will result.

12. Pay the contractor promptly for completed work and reduce to a minimum the retained percentage on partial payments; the financial responsibilities of the contractor are extensive.

LESTER C. ROGERS, M. ASCE

President, Bates and Rogers Construction Company, Chicago, Ill.

Labor-management problems in the construction industry

More than a century ago, when my father's grandfather started the construction of the first lighthouse for the budding lake port eighty miles north of Chicago, now the thriving City of Milwaukee, Wis., that hyphenated term "labor-management relations" had never been thought of, much less heard, in the sparsely settled and booming area of the Northwest Territory.

Doubtless Great-grandfather Jake simply picked out a few of his neighbors whom he knew were skilled with the saw and square, the stonecutter's tools, or the No. 2 shovel, made a deal with them, and all went to work to build a lighthouse. "Jurisdictional disputes," another unheard-of phrase and unknown problem, were settled before they arose by great-grandfather's assignment of the tasks each man was to do.

Good Labor Relations Essential

Close and sound relationships between management and labor in the construction industry have always been essential. Construction, except in a very few limited areas, is not in any way a line-production or factory process where the artisan performs exactly the same task day after day after day.

Therefore in this field, whether in a small concern or a large one, reliance must be placed at all times on the ability of the individual craftsman and the foreman to make quick decisions with good judgment in all sorts of constantly developing emergencies ranging from minor matters to crucial dangers.

The crane operator swinging large loads in a high wind, the steel gang setting and fastening the framework of bridge or building high above the ground, the sandhogs burrowing away below the surface in water and muck held back only by the pressure of compressed air and the know-how of the men, the tractor operator "dozing" a trail along the edge of the cliff, the carpenter throwing in bracing when rain-softened earth loses its stability—all these men together, and each of them separately, have in their own hands in large measure the ability to make a success or a failure of that particular contract. Thus mutual respect, good relations, and above all, intelligent understanding between management and labor in construction are of the greatest importance.

In the early years of this country's history the relation of manager to labor was in large degree that of a supposedly benevolent despot with a paternalistic interest in his workmen which covered both his trade and his morals.

The carpenter apprentice was bound out in his middle teens for a five-year period to learn from his master "the art, trade, or mystery of house carpentry." While he was absorbing the "mysteries" of his trade, the young man was prevented by the terms of his indenture from playing cards, dice, or any other "unlawful" game. Ale houses, taverns, and gaming places were not to be frequented. Nor was the apprentice to marry during the period of his indenture. And to quote,

"Nor shall he commit any acts of vice or immorality which are forbidden by the Laws of the Commonwealth; but in all things, and at all times, he shall carry and behave himself towards his said Master, and all others, as a good and faithful Apprentice ought to do."

In return for this exemplary conduct, the master contracted to teach the apprentice as long as he could learn, and to provide him with suitable clothing, board and lodging, two washings per day, three months of schooling in the evenings of the winter months, and a set of carpenter tools when he completed his indenture.

But the men who had risked so much to come to the shores of this new continent were independent souls who believed in the inherent worth and dignity of the individual and who wanted freedom from domination, whether paternalistic or tyrannical.

Early Efforts to Organize

Faint stirrings of opposition to the authority of the contractor appeared in attempts of the master carpenters in Philadelphia to organize for the purpose of fixing wages and enforcing a closed shop, even before the Declaration of Independence was written.

In 1802, the carpenters of Savannah, Ga., petitioned the legislature to incorporate them into a union so that they would have "equal level and recognized social footing with others."

A few decades later, as the nation grew, men of great courage and skill were pioneering with the same spirit of independence in the development of an industrial establishment which was to make the United States unique among the nations of the world. These giants of industry and finance believed completely in free enterprise and their own individual freedom to follow whatever course of action in

their judgment would bring financial success. The only "social security" they wanted was that which came by the sweat of their brow, the hardness of their nerve, and the skill of their hands and brains.

In their drive for success, many of them were ruthless in their tactics with the public, with their competitors, and most important, with their own labor. Decency, fair dealing, and human rights were frequently brushed aside in the mistaken idea that men who worked with their hands were made of clay inferior to that of the manager. Many an owner believed that the great financial risks he took could legitimately be passed on to, and squeezed out of labor for, after all, had he not developed the jobs which the men held?

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Labor Under New Deal

The mushroom development of the unions occurred, of course, with the depression and the advent of the New Deal with its drive for voting power and its unscrupulous and dangerous pitting of class against class. Although the New Deal worked most closely with the leftish mass unions, the pace set by these mass unions and the pressures developed thereby in the rank and file of all workers forced the leaders of the more conservative crafts unions to fall in line if they would not lose their leadership to more radical factions.

Furthermore, under the New Deal, the Federal Government became the chief buyer of construction through direct contracts by its various agencies and through subsidies to the states. Since the New Deal was determined to advance unionism, the Federal Government stipulated in its contracts and subsidies that the wage regulations and job requirements should be the union wages and union regulations of the areas. The pendulum of power had now swung far in the opposite direction from the days of the eighteen nineties.

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Every major economic and social trend, such as the growth in strength and numbers of union organization, has both good features and bad features. Mainly in the early days, the growth of the unions tended to improve the standard of living of the working population. To many contractors the existence of a pool of craftsmen, assembled and available through union offices in the larger cities, has been a decided advantage. Furthermore, while there always have been, and always will be, many irritations and dissatisfactions in dealing with and working through union organizations, it probably can be said that these same irritations and union demands for high wages have had some tendency to make construction management more efficient and more resourceful in an effort to keep costs within a competitive range in the face of high labor rates and expensive working rules.

Jurisdictional Disputes

On the other hand, there are serious defects in the situation. There is no need to outline the unfortunate aspects of the alleged domination of the individual and his output in some areas, nor to point out the economic waste resulting from featherbedding rules of which some trades are accused. The fact that each international union is a collection of autonomous locals often makes it difficult for the international to maintain discipline in all locations.

By far the worst problem which has arisen to plague the owner, the contractor, and the unions as well is that of jurisdictional disputes. These result from technological developments, the introduction of new materials, new methods, new machinery, and similarity of job types, combined with the not unnatural struggle by union officials and their unions to seize every class of work which, by any stretch of the imagination, they can argue should be handled by their particular craft. For example, untold thousands of dollars were lost thirty years ago by workers, contractors, and owners over the question of whether sheet-metal workers, iron workers, or carpenters should place the then new metal trim and corner beads which were being substituted for wood.

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However, the American Federation of Labor is organized so that each international union is a sovereign power, and in forming the Building and Construction Trades Department within the Federation, the nineteen international unions involved granted to the Department only certain limited authority. This same situation holds true with the overall authority of the American Federation of Labor itself.

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It has frequently been proposed that the easy solution of this unsatisfactory condition is to turn to the non-craft, C.I.O. type of organization, but this involves the probable loss of valuable features of the existing status. For example, there is a pride of craftsmanship developed in the apprentice training and from experience through the years. It may be argued that such pride no longer motivates the craftsman, but unbiased examination will show that it does exist, that it is worth while, and that it should be encouraged and developed rather than discarded. As we have already pointed out, reliance on the craftsman in construction—on his skill, experience, and integrity—is a fundamental necessity.

In the past, in only three cities—Boston, New York, and Chicago—have the international unions recognized local settlements of jurisdictional disputes by local boards composed of union and contractor representatives, as binding on the local and international unions. The local boards in these cities have handled the problem with great skill for many years and have never conflicted with the previous national decisions which had been made.

The great swing of the pendulum from the side of the giants of industry at the end of the nineteenth century to the side of the giants of labor unions within the last two decades, brought with it the same opportunities and the same tendencies for abuse of power. The American citizen, though, still can and does rebel against undue concentration or misuse of power in any segment of society.

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low through on all phases of this carefully formulated and agreed-on plan, the plague of lost time from jurisdictional disputes would be at an end. Of course, such perfection is to be hoped for, but is seldom achieved. In some instances contractors have failed to assign work in accordance with the correct area practice. In other cases contractors have closed down their work through a mistaken idea of their duty or because of bad feeling. In many cases one union or both unions have walked off the job, sometimes deliberately and sometimes because of lack of control of the local by the international.

Although there have been many defections of this sort, most of them have been minor in the loss of time involved, and they can be overcome to a large degree by better education of both parties as to their rights and duties, and by greater integrity and discipline on the part of the signatories with regard to the moral and practical value of their written word.

There has been one instance of a serious defection from the signed agreement. One group of specialty contractors and the union which they employ gave notice of their intention to withdraw from the plan because of a decision unfavorable to this union. This is one of the nineteen unions supposedly bound by the stipulation signed by the president of the Building and Construction Trades Department. It is self-evident that every decision by the Joint Board must militate against one or more of the parties involved. There must be sufficient moral integrity in the parties to accept adverse decisions when they come if the plan is to succeed.

A withdrawal from the signed pledge, such as has been described, poses many complications and endangers the rights of construction employers and unions who are faithful to their agreement. Architects and engineers, as well as owners, can take action to prevent similar defections by means to be suggested later.

The Joint Board actually has been very effective in reducing the lost time and attendant costs of jurisdictional disputes. It has handled, in the four years of its life, some fifteen hundred cases involving work stoppages and many times that number where no stoppage of work was involved. The Board has processed these cases largely through encouraging settlements mutually developed by the parties without resort to expensive legal procedures, except in a very minor number of instances. Perhaps one of its major contributions has been the development of a sound and workable method for the orderly settlement of jurisdictional disputes—one of the fundamental needs in the construction industry. It also has been instrumental in bringing about final settlement and agreement on a national scale of several of the most difficult and long-standing disputes between certain trades.

Disputes Can Be Cut Down

Owners and, more important, their advisers the architects and engineers, can assist in the excellent work of the Board and can aid those unions and contractors who are honestly and earnestly endeavoring to reduce the cost and incidence of jurisdictional disputes.

Most jurisdictional problems arise in highly specialized fields of work, especially in construction of buildings. When the architect or engineer draws his specifications for the specialty phases of his project, such as the heating, plumbing, or electrical work, he, in effect, sets the pattern under which the subcontractors will attempt to work.

It is not to be expected that the consulting engineer can be aware of all the changes, agreements, and customs with regard to union jurisdictions in the many geographical areas into which his design work takes him. But if he were to consult with local trade association representatives or experienced contractors in the region before he published his specifications, he might well avoid inadvertent invitations to jurisdictional trouble.

Then, as a very significant step, it is suggested that architects and engineers, in drawing contracts and specifications, include a clause in their contracts, requiring each and every general contractor and each and every subcontractor to sign an agreement to come under the Joint Board for the Settlement of Jurisdictional Disputes and to be bound by its findings. This would benefit owners by greatly reducing the likelihood of costly jurisdictional delays. At the same time this requirement would protect both contractors and unions who are seriously trying to make the plan work. It is to be hoped that such a clause might become standard practice in building contracts.

These suggestions are not partisan in any sense of the word but, as a matter of fact, serve the best interests of everyone—the owners, the architects, the engineers, construction management, and the labor unions alike. The Washington, D.C., staff of the Associated General Contractors, the chapter secretaries, or any contractor will be happy to furnish all possible necessary and pertinent data in connection with this suggested advance in which we as engineers, architects, and contractors can cooperate.

Responsible union leaders recognize the value of good contractor-union relationships in promoting steady work, and they recognize the serious threat of jurisdictional strikes to their unions and to the construction industry. Only two months ago, the nineteen general presidents of the international unions affiliated with the Building Trades Department passed a resolution banning picket lines in the case of jurisdictional disputes. This is a definite step forward in preventing work stoppage.

Slowly but with increasing certainty, the unions are coming to realize the responsibility and the dangers inherent in having practically a monopoly of the labor supply. Although their paths seem at times to diverge considerably, there is no question but that the ultimate aims of both the contractors and the top craft-union leadership in the building trades coincide in a mutual desire for a stable, profitable construction industry.

There are hopeful and constructive signs. Both labor and management are constantly working toward more reasonable understanding. We need to be rid of control boards which stimulate wage and price increases instead of stabilizing them. We need to be rid of governmental and political interference in the guise of so-called "emergencies." Then, once again, full responsibility can be placed on the unions to put their own houses in order. Contractors and the unions will be free to bargain together without government interference, and increasing good can result.

That phase of human relationships which involves the contacts and the contracts between management and labor will always be an intriguing, baffling, and most important problem for the responsible top leaders in labor, engineering, and construction. It is an ever-present problem for which there can be no permanent solution. If approached with integrity, good will, and a desire for real understanding, it is a rewarding and profitable study and will doubtless reappear as a subject for the agenda of the second Centennial of Engineering.

(This article is based on the paper presented by Mr. Rogers before the joint session of the Construction Division and the Associated General Contractors of America, Inc., at the Centennial Convention in Chicago.)

FRANCIS DONALDSON

Vice-President, Mason & Hangar, New York, N.Y.

Mechanization has revolutionized construction work

Someone has defined engineering as "the art of doing with one dollar what any fool can do with two." This definition is true as far as it goes, but it covers only one of the two phases of engineering, the second being to do things that no fool, no matter how well supplied with dollars or man-hours, can do at all.

The first phase of engineering began before recorded history, with the invention of the first tool—perhaps a shovel with which some cave man leveled his sleeping place. The second phase began ages later when mankind learned how to utilize mechanical power so as to deliver large, continuous flows of energy to a small delivery point. The first phase will be described by drawing comparisons between ancient and modern engineering works.

First Phase of Engineering

Earthwork and Masonry. Going back some six or seven thousand years to ancient Babylonia, the Mesopotamian irrigation systems, by which the waters of the Tigris and Euphrates were spread over millions of acres of desert sands, involved quantities of excavation and fill comparable to those of the largest modern schemes. The Great Pyramid of Egypt, containing three million cu yd of masonry, the biggest individual block in the world until Grand Coulee Dam, was built about 2700 B.C. The Great Wall of China, still by far the world's greatest connected masonry structure, containing approximately 300 million cu yd—thirty Grand Coulee Dams—was built over a century before Christ.

These projects were all built with primitive tools, long before even the word "mechanization" was thought of. Yet they were built, and it is interesting to compare the man-hours required per cubic yard with those for similar work today.

The cost records of the Mesopotamians, like King Ozymandias himself, are long since covered by the desert sands, but records of similar projects performed in India by primitive methods in modern times give some idea of the labor involved. On canal excavation in earth, a well organized gang consists of a shoveler who loads baskets containing about $1/3$ cu ft each, a lifter who raises the baskets to the heads of the bearers, and for a moderate haul—say, 300 ft—three bearers who carry and dump the baskets. This gang should move about $1/2$ cu yd per hour at a labor cost of 10 man-hours per cu yd. By comparison, one man on a 12-cu yd carryall scraper will handle 120 cu yd per hour at a labor cost of approximately $1/60$ man-hour per cu yd, if we include another man for maintenance labor—a 120-to-1 improvement.

The construction of both the Great Pyramid and the Great Wall of China involved quarrying and masonry work rather than excavation. Herodotus stated that to build the pyramid required the labors of 100,000 men for 20 years, but John Anderson Miller believes that this maximum labor force worked only during the flood period of the Nile or about three months a year. If we adopt this assumption and allow further for periods of building up and tapering off of forces, the labor cost per cubic yard comes to 400 man-hours. A similar juggling of the figures reported for the Great Wall indicates a cost of about 150 man-hours per cu yd. It is to be expected that a 480-ft pyramid would cost much more per unit of volume than a 30-ft wall, but to make another comparison, the labor cost of the $10\frac{1}{2}$ million cu yd of concrete in Grand Coulee Dam was perhaps 3 man-hours per cu yd, including the manufacturing cost of the cement.

Quarrying. Vast quantities of stone were quarried by the ancients for their magnificent masonry structures, and until fire setting was invented by the Romans, quarrying was the only known method of excavating rock. The old artisans, quarrymen, riggers, and masons became extraordinarily skilful in the production, transportation, and setting of stone building blocks. They freely used monoliths of sizes and weights which, with all our machinery, we would not attempt to handle today. Three wall stones in the Acropolis of Baalbek weigh 800 tons apiece, and numerous Egyptian obelisks weigh 200 to 400 tons each.

Monoliths. For quarrying and shaping stones, the Egyptians used bronze core-drills and saws, cutting by abrasion with sand fed to their edges, but how they moved and set the stones is not certain. It is thought that they constructed in-

Ancient methods of dirt moving were similar to those used to dig Lerma Canal in Mexico (near right). There 30-mile canal section was taken out in baskets in 1943 at cost of 7 cents per cu yd. In contrast, mechanized methods include use of Caterpillar pusher-loaded scrapers and motor grader (middle view) on railroad right-of-way in Brazil. At far right, International TD-24's pull Euclid loader, which can handle 1,200 cu yd an hour.

clined planes of earth or rubble and dragged the blocks on sleds or rollers up the planes and into position. To pull a 400-ton obelisk thus up a 10-percent grade must have required a tug-of-war team of about 2,000 men.

Centuries later the Romans moved several large obelisks and many smaller ones from Egypt to Rome. By this time they must have learned to use the block and tackle and to apply animal power, but at any rate they reerected the obelisks and made no fuss about it.

Some 1,500 years later, at the behest of the Pope, an engineer named Fontana lowered, transported, and re-erected one of these obelisks, and his feat was considered a milepost in engineering construction. Engineers came from all over Europe to watch the operation. His method was to construct around the column a timber scaffold strong enough to carry a number of large fall blocks, to lead their fall lines to horse-driven capstans, and by simultaneous operation to raise and lower the 330-ton column onto a cradle. After the cradle was dragged on rollers to its new location, the scaffold was reconstructed and the lifting operation repeated. It required 40 capstans, 80 horses, and 400 men. [CIVIL ENGINEERING, April 1934, p. 228.]

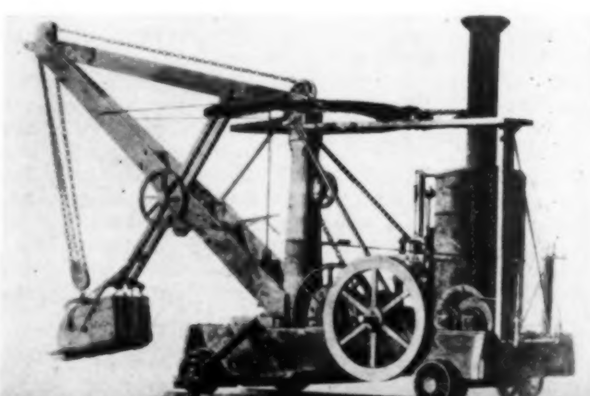
Probably the biggest job of this kind in history was the quarrying, transportation, and erection, by the Fontana method, of the Alexander Column in St. Petersburg, now Leningrad. This monument, which still stands in the Palace Square, consists of a base 24 ft square and 6 ft high, a 20-ft pedestal, and a shaft 13 ft in diameter and $98^1/_2$ ft high, all of granite, surmounted by a bronze capital and a bronze statue. The stones were quarried in Finland and brought by barge on the River Neva to a point near the site. The base weighs 300 tons and the shaft 1,100 tons. This work, done in 1834, before mechanical power had been applied to construction work, was an extraordinary feat, yet it apparently never created a ripple of interest. How many of the engineers of today have ever heard of it?

Rock Excavation. Rock excavation as we know it today was unknown to the ancients for it depends on the use of explosives. The application of gunpowder to the breaking of rock was really the beginning of the second phase of engineering. Subaqueous excavation of earth or rock was also impossible for the ancients, but they understood the construction of cofferdams and the lifting of water by man, animal, and wind power. One of the earliest tunnels on record was thus built under the Euphrates River.

Mining and Tunneling. The art of mining, including shaft sinking and tunneling in rock and dry earth, was well advanced long before the time of Christ. Earth was dug and rock chiseled out by hand, at least until the Romans began the fire setting technique. It must have been fun to work in a tunnel in those days—to build a wood fire against the face, wait until the surface rock became red hot, fight your way in through the fumes and throw cold water on it, and then muck the spalled fragments. In comparison, today's silicosis would be a pleasure. Muck was hoisted by man or animal power or carried up ladders on human backs.

In spite of all these difficulties, the Romans built some notable tunnels, the greatest of which was holed through in the first century A.D. to drain Lake Fucino. Dr. Drinker states that this tunnel had a section 19 ft high and 9 ft wide, was over three miles long, and was driven from 22 shafts or slopes, some nearly 400 ft deep. According to reports, 30,000 men were employed for 11 years to build it. It is obvious that even by working four shifts a day it would be impossible to employ 7,500

First successful steam shovel (at right) was invented and built by William S. Otis of Canton, Mass., in 1837. Seven such machines were built having dipper capacity of $1\frac{1}{2}$ cu yd. Today, Marion diesel-electric excavating shovel used on Fort Randall Dam (middle view) has capacity of 10 cu yd. Bucyrus-Erie walking dragline, seen stripping overburden at Danville, Ill., open-pit coal mine (far right), handles 30-cu yd bucket.



men in a shift in 40 or 45 headings of this size, so it is likely that the report means that 30,000 different persons worked on the job in eleven years. The labor turnover must have been high and the casualties terrible.

If we assume that all shafts and headings were worked simultaneously with as many men as possible, and if we rationalize an employment curve, we find that the average daily advance comes to 3 in. per heading per day, and the labor cost to 300 man-hours per cu yd. Compare this with the daily progress on the 25-mile Downsville Tunnel of over 40 ft a day, and a labor cost on modern hydro tunnels in Scandinavia of 1 to $1^1/_4$ man-hours per cu yd.

Pumping. Throughout the ages the handling of water has been one of the most important tasks of the engineer. For this purpose various sources of power other than animal muscles have had their first application—such as the wind and flowing water. Here again the concentration of power inaugurated by the steam engine opened new possibilities.

Allied with the handling of water is the finding of it. The evolution from wells dug by hand to drilled wells was slow. Real development of the art of drilling waited on the development of mechanical power.

Second Phase of Engineering

And now for some examples of things the ancients could not have done, some things that come under what I have called the second phase of engineering:

- Structures depending on steel in large quantities and in many different shapes, such as skyscrapers, towers, deep cofferdams, large bridges.
- Construction work made possible by a concentration of power through the use of steam and internal-combustion engines, electricity, compressed air, hydraulic pumps in various combinations. Under this head come deep mine shafts and deep mining, deep dredging in harbors and seas, excavation in wet ground requiring predrainage, compressed-air caissons and subaqueous tunnels, river diversions, deep drilling.
- Means of rapid transportation made possible by concentrated power—railways, automobiles, boats and ships, and finally, greatest of all, human flight.

As mentioned previously, the two phases blend. At Grand Coulee the earth and rock excavation could have been performed, the sand and gravel dug, and the concrete mixed and placed by hand, given enough workers and enough time. But no Pharaoh, however powerful and however ruthless, could have diverted the Columbia River between floods. Neither could he have commuted to work in the morning as do millions throughout the world, or have traveled from Cairo to Chicago in 30 hours.

Coming now to the more recent past I shall discuss the application of mechanical power to the various branches of engineering.

Earth Excavation and Equipment

The shovel improved with the discovery and application of metals; the hammer developed into a pick; and, after the wheel was invented, the wicker basket turned into a wheelbarrow and the barrow into wagons and carts drawn by animals. Someone combined the ideas of shovel and sled and created the horse-drawn drag scraper. Then, for longer hauls, wheels were added and wheeled scrapers and fresnos came into being. In the flatlands our railways were largely built with these.

In through cut, in hard earth or rock, the picked or broken materials had to be shoveled by hand. The best vehicle for transporting the material proved to be the two-wheeled tip cart drawn by a single horse or mule. Its capacity was small, and except for short hauls, a wagon drawn by two or more horses was a cheaper means of transport.

Suction dredges have grown in capacity up to 5,000-hp 30-in. giants like the *New Jersey*, here pictured in 1933 when owned by Great Lakes Dredge & Dock Co. This huge Bucyrus-Erie diesel-electric dredge is now owned by Standard Dredging Co.

To meet this problem in soft ground the elevating grader was devised. This consists of a wheeled scraper with a scoop designed so as to discharge its load continuously onto an elevating belt discharging in turn onto a transverse loading belt. Drawn by several teams of horses, this grader could deliver a steady stream of dirt to a wagon traveling beside it and could move 40 to 50 cu yd per hour. The development of the tractor made possible an increase in capacity to 150 cu yd per hour, loading trucks instead of wagons. Now one company makes a grader which, propelled by two 20-ton tractors, has a capacity of 1,000 to 1,500 cu yd per hour.

The Power Shovel. The real revolution in dirt moving began with the steam shovel, invented in 1835 but coming into use in the eighties. The first practical model was equipped with a boom which swung like a gate. Then came a boom pivoted beneath and swung from the top of a fixed A-frame, the total swing being thus limited to about 180 deg. For many years this design was followed. These machines were considered too heavy for road wheels, so were mounted on railroad trucks and operated on tracks. Though awkward, they could load any kind of material into any type of car or wagon and were employed in building most of our later railroads in hilly country, in the excavation of the great Culebra (now Gaillard) Cut of the Panama Canal, and on thousands of other projects great and small.

The railroad shovel had several grave disadvantages, namely, the difficulty and cost of supplying the boiler with fuel and water as well as the cost of frequent boiler repairs; the limited range of action due to the fixed A-frame; and most of all, the cost of grading for, and building track ahead of, the shovel as it advanced. The application, between 1905 and 1925, of two old inventions made possible a different type of shovel which obviated these troubles. The development of gasoline and diesel engines eliminated the boiler; the crawler tread not only did away with track laying but permitted the construction of a base sufficiently wide and stable to support a completely revolving shovel.

The size and capacity of the power shovel have been increased tremendously. From the original model with a $1^1/_2$-cu yd dipper, the increase has progressed through the 5-cu yd railroad shovels used at Panama to the 8- and 10-cu yd giants used today on large excavation projects. For coal stripping, one of the latest shovels has a 36-cu yd bucket, 900-hp motors, and weighs nearly 1,500 tons. Power has changed from steam, through gasoline to diesel engines. The larger shovels are electric. The controls have changed from throttle valves and levers to push buttons actuating a variety of complicated electrical and mechanical devices. The operating cycle has been reduced from more than a minute to 20 to 25 seconds, and the output has increased from about 150 cu yd per hour to more than 1,000.

Draglines. The rotating shovel made possible the development of the dragline by substituting a long boom for the shovel boom and dipper stick. The original 1-cu yd boiler-plate bucket constructed in Illinois in 1905 has been increased to a 30-cu yd monster, operated on a 200-ft boom. Another useful modification of the rotating shovel is the backhoe, which permits the machine to dig a trench behind itself. Backhoes are now available in sizes up to $1^1/_2$ cu yd.

Grab Buckets. The grab bucket, especially the clamshell type developed by Leonardo da Vinci, has evolved into many forms: digging

At Fort Randall Dam, tunneling equipment included saw gantry and Blaw-Knox tunnel forms (seen respectively at left and right in adjoining photo). Saw starting cut for tunnel bore (middle view) was developed by contractor, Silas Mason Co., for use in shale rock at dam site. Conway mucker of 100 hp (far right) is also seen in use on Fort Randall Dam project.

buckets with teeth for trench and cofferdam excavation; rehandling buckets for sand, gravel and iron ore; rock grapples, etc. The orange-peel has remained substantially unchanged. Standard sizes of clamshell buckets now range from $^1/_2$ to $7^1/_2$ cu yd, and for orange-peel buckets, from $^2/_3$ cu ft to 3 cu yd. The tiny size is used for hand digging in underpinning cylinders.

Caterpillar. The crawler tread applied to the tractor started a second revolution in earth moving methods. The Caterpillar tractor has become a symbol of power and determination. It is capable of drawing huge trucks and wagons and self-loading wheeled scrapers and, equipped with a bulldozer blade or other attachment, digs cellars, strips topsoil, or overturns forests. The 130-hp, 18-ton tractor has become standard equipment. It will handle four-wheel scrapers up to 23-cu yd capacity. This scraper or "pan," with a pusher tractor to help load it, will move 100 cu yd of earth per hour on a 1,000-ft haul—quite a contrast to earth moving in the days of the horse.

The crawler-tread tractor is a relatively slow-moving vehicle, hence for long hauls its supremacy is being lost to rubber-tired tractors and self-propelled scrapers. This change has been made possible by the development of huge pneumatic tires. A recent scraper of this type has four wheels under the tractor end with tires 12 × 24 in. and 24 × 25 in., and two wheels under the rear end with tires 27 × 33 in. It has two 190-hp motors, a hauling capacity of 24 cu yd, and a speed of 30 mph.

Transportation. Scrapers excepted, digging equipment requires some means to take the dirt away. Tip carts and horse-drawn wagons have been mentioned. The old-time wagon-box body was soon replaced by a body with removable sides and loose slats in the bottom, and next by a body with bottom-dumping doors. When the rotary shovel superseded the railroad shovel and the gasoline or diesel engine replaced animal power, wagon bodies reverted to the box type but were pivoted at the rear, provided with an end gate hinged at the top, and a mechanical or hydraulic hoist to tip the body and load up to a dumping angle. Trucks of this type are now in general use and are manufactured in capacities up to 34 tons and powered with 400-hp diesel motors.

Railroad-type steam shovels were largely served by railroad equipment. For many years 4-cu yd side-dump cars drawn by steam dinky locomotives running on 36-in.-gage track were standard equipment. At one time hundreds of dinkies and thousands of cars were in use all over America. For long hauls on large jobs like the Panama Canal, 12- to 30-cu yd standard-gage dump cars were used. Such cars, modernized and dumping by compressed air, are still in use on certain railroads and in open-pit mining operations.

Even this equipment is being replaced by trucks and by tremendous bottom-dump wagons. In design, these units are much like the large scrapers already described, with capacities up to 25 cu yd and powered with engines up to 380 hp.

Conveyors. Under favorable conditions belt conveyors have been used for the transportation of material. The hauling cost is very low but they require special loaders and stackers and do not take kindly to boulders. At Grand Coulee the main conveyor for excavation had a 60-in. belt, was a mile long with a 400-ft lift, and handled 2,000 cu yd per hour.

Miscellaneous Excavating Equipment. In general, American equipment has been designed to take a bite at a time whereas European engineers have favored continuous digging with chain-and-bucket excavators. American engineers have used this principle mostly for underwater digging and for trenching machines. On large pipelines, trenching machines are used that will handle 350 cu yd per hour.

Hydraulic Excavation. When high-pressure water is available, or water and cheap power, hydraulic excavation is sometimes economical. A water jet directed against the cut by means of a large nozzle or monitor will both dig and transport dirt downhill. For a long time this method was standard practice in placer mining, and is now used for trimming slopes on the Panama Canal.

Dredges. For subaqueous excavation, floating dredges have been developed that correspond in type to the machines used in the dry, that is, dipper dredges like power shovels for hard digging; clamshells for sand and silt; and ladder dredges with bucket chains for sand, gravel, and similar digging. Dippers range from 10- to 16-cu yd capacity, clamshells to 18 cu yd. The usual gold dredge with 8-cu ft buckets on the ladder has a capacity of about 250 cu yd per hour, but several 16-cu ft monsters have been built. Ladder dredges are equipped with belt conveyors which deposit the dredged material behind the dredge (as in placer mining operations for gold), or on the banks of the channel in which the dredge is

working, or on barges for disposal away from the site.

The suction dredge is provided with a cutter head which breaks and feeds material to the suction pipe of a centrifugal pump whence it passes through a discharge pipe, usually carried on pontoons, to the disposal site. A large suction dredge may have a 30-in. discharge line capable of handling more than 20,000 cu yd of material per day to a distance of two miles, and will require 3,000 hp at the pump and 600 hp at the cutter. Some suction dredges are built as self-propelled "hopper" dredges, capable of transporting the dredge material to sea for dumping.

Similar large pumps are sometimes used in the construction of earth dams, the suction being taken from a "hog box" into which excavated material is dumped.

Compaction of Earth. Watertight earth embankments were first made by compacting the earth with human feet. Then animals were employed such as goats and sheep, and in India, elephants. Eventually rollers of different types were developed. It was found, however, that smooth rollers, no matter how heavy, compacted only the surface of the fill, so "sheeps' feet" were added. A modern sheepsfoot roller weighing 15 tons will compact an area 10 ft wide and will exert a pressure of 640 lb per sq in. on each "foot," some 6 in. beneath the surface of the fill. Such rollers are pulled by crawler-tread tractors back and forth over the fill, previously dumped and spread in 7-in. layers by bulldozers, until the desired degree of compaction is attained.

Where a dam is built by the hydraulic method, the discharge pipes are arranged so as to dump the material on the casings of the dams, the water being allowed to flow to a pond maintained along the axis of the dam and then pumped out after the solids have settled. This operation grades the material from coarse in the casings to fine in the middle.

Rock Excavation

Excavation as opposed to quarrying really began when gunpowder was used in German mines in the seventeenth century, and the art advanced rapidly with the invention of dynamite in 1870. Although blasting methods have been improved, the real problem since has been how to drill holes.

Drilling. Percussion drilling in rock followed closely on the development of steel. A man pounding a drill with a hand hammer became the symbol for rock work. Then drill teams were organized with one man to hold and turn the drill and one, two, or even three to pound it with sledge hammers. The use of the sledge became an art, and workmen were proud of their ability. For down holes a churn drill was sometimes used. This consisted of a heavy bar raised and dropped by four men.

As recently as fifty years ago a large part of the rock broken in America was drilled by hand. Hand drilling was particularly adaptable for work in the open where plenty of labor was available. In tunnels, where the area of the working face is limited, rapid progress demanded faster drilling. It was therefore natural that the first mechanical rock drills were developed for two long tunnels, the Hoosac Tunnel in Massachusetts after 1856 and the Mt. Cenis Tunnel under the Alps. The Europeans struggled with the development of hydraulic drills but Americans started with compressed air as a source of power, and today it is practically the only source.

The development of the air drill was rapid. The early models were all piston drills, which imitated the action of the churn drill. For down holes, water was poured in the drill hole and the reciprocating drill steel pumped or splashed the cuttings out of the hole most inefficiently. About 1908, hollow drill steel became available, and J. G. Leyner in Colorado made practical a drill he had invented some ten years before. This was a hammer drill, and it washed out the cutting by feeding both water and compressed air to the cutting edge through the hole in the steel. The resulting increase in efficiency soon forced the big drill manufacturing companies to buy Leyner's patent rights, and the piston drill is no more.

Hammer drills for down holes in the open are made in sizes that are hand held and require no mountings; for larger sizes the wagon mounting is standard. The guide frame, at first vertical, is now pivoted so that holes can be drilled at any angle.

For deep holes of large diameter in quarries or similar work, the churn or well drill is still used. Such drills are now mounted on crawler treads and are powered by diesel engines. The core drill or diamond drill is used primarily for exploration.

The development of hard steel for drill bits was unable to keep pace with that of the machine; in hard rock half the machine's efficiency was lost on account of the time required for handling and sharpening bits as a result of wear and breakage of their cutting edges. In America detachable bits were devised which can be changed at the drill and sharpened by grinding. German metallurgists made more durable cutting edges by brazing strips of tungsten carbide to the drill rods. The development of this type of cutting edge, interrupted in Germany by the second World War, was taken over by Sweden. In Sweden, mining and tunneling operations are far ahead of those here in this respect; I found nothing but carbide cutting edges in use there over four years ago. The Swedes have adopted the chisel-type bit whereas in this country the cross bit is largely used.

For the soft Midwestern shales, the coal saw has been modified to saw a 6-in. kerf 8 ft deep at the desired boundary of the excavation, thus making line drilling unnecessary and eliminating overbreak.

Explosives. Since the invention of dynamite, progress in the art of breaking rock has resulted from the development of explosives to meet specific conditions, as well as from the control of individual explosions. At first all shots were fired with a fuse, cut to lengths that produced nearly simultaneous or successive firings as desired. Then came the electric detonator, enabling a group

Earth movers now generally travel on giant pneumatic tires to provide maximum flotation and longer wear and handle more tonnage at lower cost. Tires on Caterpillar at left were made by Goodyear for use on highways and airports, in logging operations, and in stripping and handling ore and coal. Le Tourneau (far left) is handling clay and gravel at Trawick Oil Field, Texas.

of holes to be fired at the same instant. Finally the delayed-action exploder was developed, which now permits as many as 12 rounds to be fired in succession by a single electrical impulse.

Quarrying and Tunneling

The drilling and blasting equipment just discussed has been applied to quarrying and, in quarries producing stone for crushing, this equipment and big power shovels and trucks have lessened the labor cost tremendously. The quarrying of building stone, however, remains a laborious operation. Two additional devices have been worked out to lower labor cost, both harking back to the Egyptians but power operated. The first is a calyx drill and the second a wire saw. These cut by abrasion as of old but are now complementary. Two holes are drilled big enough to contain the sheaves around which the wire operates, and as the sheaves are gradually lowered, the wire cuts a narrow vertical kerf between them.

Shafts in Rock. Shaft sinking was one of the earliest forms of mining but was the last to be mechanized. For centuries broken rock was carried up ladders on human backs. Then winches were invented, driven by manpower, horsepower, water power and finally steam and electricity. Although methods of drilling and blasting progressed, until recently shafts were mucked by hand into tip buckets. It is worth noting that the fastest shaft sinking progress ever attained, nearly 450 ft in a month, in South Africa, depended on hand mucking.

In America, clamshell buckets are used to load large shaft buckets. In one scheme a bucket provided with an independent pneumatic closing mechanism is hoisted, by an independent engine in or on top of the shaft, only high enough to dump into the bucket, and is guided and operated by a foreman and four muckers on the shaft bottom. Another mucker consists of a clamshell bucket operated by a traveling crane, its rails being supported by a structural frame suspended by four cables leading to winch drums at the top of the shaft.

Water handling in shafts has always presented a great problem. In brief, the art has progressed from bailing to pumping, and from pumping to grouting the waterbearing fissures and thus avoiding the issue.

Shafts in Earth. Shafts in earth were first sunk by digging and timbering, and methods of forepoling and sheetpiling were devised centuries ago. The difficulty and danger of such methods forced mechanization as soon as mechanical power became available.

The first departure from the early method of shaft construction was the use of hollow caissons which sink of their own weight when the material inside is removed. Brick work soon replaced weighted timber and concrete replaced brick for caisson construction.

In 1830 Lord Cochrane conceived the idea of closing the top of the caisson and expelling the water within it by compressed air pumped through the bulkhead. This required an air lock in the bulkhead to pass men and material. His bold idea made possible the sinking and sealing of caissons in difficult wet ground much more safely.

Shaft caissons, generally speaking, will not sink much beyond 100 ft since the outside skin friction increases until movement stops and cave-ins occur. Since very deep overburden exists in certain European mining districts, other means of sinking had to be attempted. One method was to construct within the first caisson a second caisson built of cast-iron segments, which was sunk by means of hydraulic jacks bearing against a ledge attached to the first caisson. Sometimes even a third caisson was required, and depths of 400 ft have been reached successfully.

To reach still greater depths in Europe, the freezing method was developed. In this process a ring of cased holes approximately 3 ft apart is drilled around the shaft location, interior pipes are inserted, and chilled brine is circulated within the casings for several months until a huge column of frozen ground is created. The shaft is then sunk through the frozen ground and lined in the open. Scores of difficult jobs have been completed successfully in this way, and depths attained far beyond the reach of caissons.

Up to now, American engineers and contractors have been backward in using this idea, and the only job done in this country comparable to those in Europe was the recent sinking of a potash shaft in New Mexico. This shaft penetrated 350 ft of wet rock with unconsolidated layers of sand and silt, and required the drilling, by rotary drills, of twenty-eight 360-ft holes located on a 31-ft-dia circle around the shaft.

Also developed in Europe to a much greater extent than in this country is the cementation of rock fissures by drilling deep holes and grouting them in advance of excavation.

Tunnels in Rock. The demand for speed in driving rock tunnels created the pneumatic drill, and progress in the art depended for several decades upon its development. Piston drills and the heavy columns and arms upon which they were mounted were poor tools for drilling horizontal holes, and hand mucking gangs could load all the muck produced. With the rapid improvement of the Leyner drill and the introduction of drill carriages and the full-face method of drilling, mucking became the retarding factor, and a demand arose for machines.

In bores as large as railroad tunnels or larger, railroad-type shovels,

equipped with short beams and dipper sticks and operated by compressed air, were used even in the heading-and-bench days to load dump cars behind the bench. Today electric-powered rotary shovels are used; when haul is not too long, diesel-powered trucks have been used in place of cars. In small tunnels, shovel loading is not feasible, and beginning about 1915, flip-over bucket loaders came on the market. In general this type digs by moving bodily against the muck pile; the bucket then casts its load onto a belt which discharges into the car or truck. The 100-hp electric Conway loader now has a capacity of 100 cu yd per hour in good digging and will operate in a $12^1/_2$-ft circular bore. For smaller tunnels, the Eimco-type loader, whose bucket discharges directly into a car behind, is a popular and satisfactory machine.

Greater speed and better safety standards have brought forth many other mechanical improvements, of which a few can be mentioned: automatic drill feed; a carriage with drills mounted on booms which permits almost instantaneous set-up and movement; a cherry-picker or transfer platform to reduce switching time for cars behind the loader; storage-battery locomotives with quick-change batteries; cars with roller bearings; powerful blowers, discharging up to 10,000 cu ft of free air per minute through 5 miles of pipe.

Most of these improvements are American, and this country holds all records for speed in driving rock tunnels. However, in Norway and Sweden, tunnels in good rock with a cross section of 250 sq ft or more are being driven for a total labor cost of $1^1/_4$ man-hours per cu yd.

The engineers and managers seek economy rather than speed, and favor short headings. The workers cooperate, in that a member of the tunnel workers' branch of the construction union is willing to do, and does do, any kind of job in a tunnel, and the question of jurisdiction does not arise. In 1948, at Vinstra in Norway, I saw a long hydro tunnel with a cross section of 325 sq ft being driven from a number of headings, with crews of four men per heading per shift, at a rate of slightly over 10 ft per heading per day of three 8-hour shifts. At each heading the four men drilled, blasted, and mucked an average of 40 cu yd of solid rock, and in addition laid track, extended pipe and wires, and operated the dinky to the dump. All drilling was done with jackhammers on jack legs.

Tunnels in Earth. As in shaft sinking, ingenious methods of timber support for tunnels in earth were devised centuries ago, but where the ground was so wet that inflowing water carried material with it, no timbering was adequate. To overcome this difficulty the English engineer Brunel devised the tunnel shield in 1818, and in 1825 began with it to drive a tunnel beneath the Thames, which after 17 years of effort and many disasters, he finally completed. A quarter of a century later another Englishman, Greathead, improved the shield and applied the pneumatic process successfully in driving a second tunnel under the same river.

Today shield tunneling with compressed air is commonplace, and in New York City alone there are some 38 subway, railroad, or vehicular tubes beneath the Hudson and East rivers, each tube about a mile long. Greathead's shield has traveled a long way from the Thames.

The plant required for one of these tunnels, especially a vehicular bore, is most impressive. From 7,000 to 20,000 cu ft of free air must be allowed for each heading. For the four headings on the Manhattan side of the Fulton Street Tunnel, 28,000 cu ft of compressor capacity was provided, driven by 3,000 electrical horsepower. The jacks used in the shields have 10-in. plungers and work under pressures sometimes reaching 6,000 psi. Since 18 are required for a subway shield and 30 for a vehicular, the hydraulic pump and accumulators must be large.

Subaqueous tunnels are lined with bolted segments, usually of cast iron. Each segment weighs from 1,700 to 3,100 lb, so a hydraulic erector pivoted on the center line of the shield is used to erect them. Hydraulic and pneumatic bolt tighteners have been used to do the heavy work of bolting the segments together.

Usually muck taken in through the shield pockets is moved to the shaft in cars. At the Sumner Tunnel under Boston harbor, the excavated clay was transported from the heading to the disposal bins by belt conveyors in the tunnel and by a scraper conveyor up the shaft. An ingenious double-barreled lock with gates and air valves that opened and closed automatically was used successfully to carry the stream of muck through the air bulkhead.

Foundations

Deep foundations are essentially modern. The ancients had to rely on the ground as they found it, and bad guesses as to underlying material damaged or wrecked innumerable great edifices. With mechanical power came the ability to reach a firm stratum—by boring for explorations, and by deep pile driving or by shaft sinking methods for support. Foundation failures have become relatively rare.

In ancient days piles were driven by hand power, and later, after the invention of leads, by tripped drop hammers raised by winches. Penetration and supporting power remained low until the steam hammer

At Alameda Air Base near Oakland, Calif., wood and composite piles are driven on 5 to 12 batter to close tolerances by two Universal rigs of Raymond Concrete Pile Co. One has 80-ft leads and weighs 80 tons, the other has 96-ft leads and weighs 85 tons.

was adapted to pile driving, when it became possible to drive piles to depths of 80 to 100 ft. Large leads were developed to handle a heavy hammer and long piles, their bed frames resting on greased rollers for movement forward, backward, and sidewise. Leads are now usually carried on a rotating frame, similar to that of a power shovel and mounted on wheels or crawler treads. For water work they are carried on a scow.

Two types of hammers are in use, the Vulcan, a long-stroke machine in which the steam only lifts, the hammer falling of its own weight, and the McKiernan-Terry or double-acting type of hammer. The Vulcan is generally used on large wooden piles, and the McKiernan-Terry on steel piles and sheetpiling.

Unlike other branches of construction work, pile driving has not progressed much since the steam hammer was perfected, although the man-hours per pile have been reduced. For wood piles the record was made in 1918 at Hog Island, when one crew drove two hundred and twenty 65-ft piles, an aggregate length of 14,300 ft, in nine hours.

Other types of piles developed in the last three or four decades are the H-beam pile; the blown-out pipe pile; the Drilled-In caisson, combining drilling and driving; various concrete piles; and most important, the interlocking steel sheetpile, which makes possible open excavation to much greater depths than before. One of the box cofferdams for the George Washington Bridge was 85 ft below the water surface at the deepest point.

In addition to cofferdams of various types, caissons, open and pneumatic, are particularly suitable for bridge pier foundations. The limit of compressed air work remains at a little over 100 ft below the water surface, but many open caissons in suitable material—silt or soft clay—have been dredged to much greater depths. One of the Tacoma Bridge caissons was sunk to a depth of 225 ft.

Building Construction

In the field of buildings, we excel the ancients in the use of only two materials, structural steel and concrete. Steel erection methods have changed little since structural shapes became available; guy derricks are used for buildings and various kinds of travelers for bridges. The use of air hammers for driving rivets has become universal. Autogenous welding by gas or electricity is being used more and more in steel fabrication of all kinds. The big advance has really been in the production of more useful sections, which the Gray mill, invented in England and brought to this country in 1904, made possible. Rolled girder beams 36-in. deep and weighing 300 lb per ft, and H-columns with a 125-sq in. cross section are in common use.

It was found that smooth rollers, no matter how heavy, compacted only surface of fill, so "sheeps' feet" were added. Here top of a dam is rolled with two International TD-24's, each pulling four sheepsfoot rollers, or 40 tons.

The increasing use of concrete has necessitated the development of so many appliances that they can only be listed:

Rock crushing and screening plants with capacities up to 1,000 tons per hour. A big primary breaker has jaws with a 5-ft 6-in. × 7-ft 0-in. opening and it weighs 280 tons.

Automatically controlled conveyors for handling all materials in the plant and thence to the batcher plant.

Pneumatic equipment for unloading bulk cement from cars, storing it in silos, and delivering it to the batcher.

Automatic weighing and recording batchers which control the ingredients of each batch of concrete within 2 percent.

Mixers may be divided into: stationary, with tilting conical drums for control plants, up to 6-cu yd size; truck-mounted for delivering concrete over wide areas, water being added and mixing carried on en route; crawler-mounted, with tandem drums for rapid paving; and others for special purposes.

Equipment for conveying concrete to the forms includes crawler cranes; long-boom whirler cranes on tracks; giant cantilever cranes; cableways; Rex pumps and pneumatic blowers.

Pneumatic and electric vibrators for compaction.

Refrigerating equipment and freezing plants for chilling aggregates and mix water.

Incidentally, the Grand Coulee Dam still has the record for fast pouring and is likely to keep it for some years to come. In October 1939, a total of 530,475 cu yd were placed in the dam.

Where Are We Going?

In this outline of the history of certain phases of construction work and the development of their mechanization, we have seen animal power replaced by steam and steam by internal combustion engines and electric motors. We have noted the invention of new equipment and the tremendous increase of efficiency of all tools both new and old. We have watched the machines for handling large quantities of materials themselves grow bigger and bigger. But what we may not have realized is that the rate of improvement of things mechanical has increased in recent years. We are on the fast rising portion of the logistic curve.

In short, we are acquiring the ability to rebuild the earth and the question arises, How do we want it rebuilt in order to make it a better place in which to live? Certainly if we restore our wasted soil, conserve our forests, purify our waters, and eliminate our dreadful slums we shall be on the right path. But if all we do is to cover our urban areas with skyscrapers and factories and our countryside with transmission towers and concrete superhighways, and convert all our rivers into chains of lakes by building more and greater dams, then, no matter what our purpose, I doubt if we shall be any better off. It is high time for engineers in general and construction men in particular to ask themselves "Where are we going?"

(This article is based on the paper presented by Mr. Donaldson at a Construction Division session presided over by A. H. Ayers, chairman of the Division's Executive Committee, at the Centennial Convention in Chicago.)

Construction by contract method—

Because civil engineers and general contractors are members of the construction team which has done so much to make the United States a leading nation of the world, this joint session of the Construction Division of ASCE and the Associated General Contractors of America is particularly appropriate.

In recent years there has been a steady increase in the proportion of men in executive and ownership positions in general contracting firms who are civil engineers. This, we believe, indicates that the business of construction is constantly becoming more complex so that a sound engineering training is essential, and also that there is constant improvement in the quality of construction men.

Certainly it is significant that the Construction Division of ASCE has grown from its original membership of 1,615 when it was established in 1926, to more than 12,300 at present, making it ASCE's largest Technical Division. This is perhaps appropriate because construction now has become the largest single industry in the nation. ASCE records show that approximately 40 percent of the membership of its Construction Division are owners, executives, or managers of contracting companies.

The subject assigned to me is the development of the construction industry and the contract method in the United States. This subject is so vast that little more than a brief introduction to it can be given here. There is a wealth of material but it is mostly uncoordinated. Apparently those who have been engaged in the construction industry, not only in this country but throughout the world in all ages, have been so busy doing their job that they have not taken the time to record their activities for future generations.

My purpose here is to mention briefly a few highlights to illustrate significant points about the construction industry and the vital part it has played in the development of the nation.

Construction Through the Ages

The history of the human race is in large part the story of man's struggle with his environment. In that struggle the basic needs of men and women have been food, clothing, and shelter. Of these the most durable is shelter. As far back in history as archeologists have been able to find traces of human life, they have also found evidence of construction. Presumably one of the first wants of man was shelter for himself and his family.

As soon as civilizations began to develop there arose the need for structures and facilities for the production of goods, trade and commerce, transportation, education, religion, the development of natural resources, public buildings, safeguards to health, life and property, and the many other types of facilities which our modern civilization has found necessary or desirable.

Little is known about the construction industry in early times when the wonders of the ancient world were built. But in ancient Greece, when many structures were built which are still famous today, Greek law and custom prescribed relationships between the contractors and the government which are strikingly similar in principle to the contractual relationships prevailing today.

The contractors were required to work continuously, to hire sufficient numbers of qualified workmen, and to guarantee quality of performance. There were penalties for delays or failure to complete the work. Payments were made in installments as columns or pediments rose to completion. The precedent was set that a percentage of the contract price be retained until the project was completed.

It was during the days when Imperial Rome ruled a great part of the world that construction companies much as we know them today came into being. Their Greek predecessors worked independently in small groups. But the Roman contractors formed large companies to undertake the huge construction projects of the time. They came to realize the complexity and the risks which were involved. They believed that by incorporating many talents under a single management the risks could be minimized and better controlled. The Romans who undertook whole projects were awarded their contracts under a bidding system similar to that which exists today.

After the fall of Rome the construction industry as such seems to have generally faded from view. Construction of a durable nature that was continued during medieval times seems to have been carried on mainly by the churches, whose efforts were concentrated on the building of cathedrals, abbeys, and works of that nature.

In Egypt, where it has been estimated that there were barracks for 4,000 workmen to prepare the stone for the great Pyramids, and in Mesopotamia where there were vast irrigation projects, much of the actual construction work was done by slaves, who were often prisoners of war. This custom seemed to prevail also in Greece and Rome, although some of the more skilled workers were free men. The designers, who were also responsible for the execution of the work, were men in high positions at court.

What little is known about the contractors of medieval England points to their having risen out of the ranks of the free masons. Training was later specialized to develop two types of masons: one skilled in the actual stonework and the other in the planning and designing of buildings. The former apparently was the forerunner of the modern contractor; the latter, of the modern architect.

Rules for the mason's craft were drawn up in London in 1356. One of the most interesting rules is one which provided for a guarantee of ability and responsibility. As described by Martin S. Briggs in his, *A Short History of the Building Crafts:*

> Anyone undertaking a contract was to come before the good man for whom he was going to work, with four or six experienced masons who should swear that he was capable of doing the job, and that if he failed they would themselves complete the work on the same terms.

In early England, the builder was the master mason who fulfilled the three functions of designer, builder, and master of the works. In the latter capacity he supervised the operations to make certain that they were done properly and that the workmen were paid according to their ability.

an American tradition

H. E. FOREMAN, Managing Director
The Associated General Contractors of America, Inc.
Washington, D.C.

Development of Construction Industry

While the construction industry as developed in this country is unique, just as the nation itself is unique, its principal traditions came from England. The early methods, materials, contract forms, and practices of the industry came primarily from England and from the other European countries from which the settlers came.

Written contracts were in use in the early days. Sumner C. Powel has reported, in the *Journal* of the Society of Architectural Historians, that the first full contract recorded in the town book of Sudbury, Mass., in 1642, provides in part as follows:

> . . . the said Ambrose doth promise to build a sufficient cart bridge over the river three foote above highwater and twelve feet wide from the one side of the river to the other, provided that the towne doth fell & cross cutt the tymber and saw all the plank and carry it to place and when it is ready framed, the town doth promise to help him to raise it.

In another contract in Sudbury, dated February 17, 1642:

> It is agreed between the townemen of the towne on the (one part) . . . and John Rutter on the other part that the said John . . . for his parte shall fell, saw, hew a frame house for a meeting house thirty foote long, twenty foote wide, eight foote between joynte, three foote between studde, two cross dorments in the house, six clear story windowes with four lyghts a peece and foure with three lyghts a peece and to ententise between the studde which frame is to be ready to raise the fourth week in May next.
>
> And the towne for their parte do covenant to draw all tymber to place and to help rayse the house being framed and allsoe to pay to the said John Rutter for the said house six pound, that is to say three pound to be paid in corne at three shillings a bushell or in money in and upon the twenty-seventh day of this present month and the other three pounds to be payd in money, corne or cattle, the corne and cattle to be prized by two men of the town, one to be chosen by the towne and the other to be chosen by John Rutter, and to be paid at the time that the frame shall be by the said John Rutter finished.

The American construction industry did not get its real start until after the Revolution. England had used the American Colonies primarily as a source of raw materials for its factories. Much of what was built during Colonial days was done by the British or under their direction. It was not until the United States became independent that it set out by its own efforts to become self-sufficient.

After the American Revolution there was the immediate need for structures to house manufacturing processes so that goods formerly supplied by Great Britain could be produced at home. *The American Peoples Encyclopedia* reports that:

> The history of construction in the United States reflects in an exaggerated form the forces of industrialism which combined to cause fundamental changes in building, and to constitute the activity as an "industry" in its own right throughout the Western civilization.

As a result of the need for large industrial buildings, the Encyclopedia reports, the amateur designer and the anonymous builder yielded to the professional architect and workman, and building design changed to meet new needs. Techniques and methods still followed earlier procedures. But the needs of factories for large rooms, for floors and walls of great strength to support heavy machinery, for illumination, temperature control, and ease of mobility for materials and personnel, demanded more than could be supplied by previous structural theories and customary techniques. These demands led to the development of new techniques.

A decisive point in the history of American construction, the Encyclopedia reports, was the elevation of the mechanic to the rank of engineer, with a professional status distinct from that of the architect. The Encyclopedia adds:

> The engineer's dedication to technology assured the rapid development of new methods and new processes to which subsidiary industries could contribute an increasing share.

Early American Construction

Some of the construction work done during the first half of the last century gives an indication of how the industry developed, and how important it was to the opening up and development of the country. For more than two hundred years after the early settlements were made in Virginia and New England, the rivers were the principal highways and Colonial America expanded along those waterways, first up the rivers flowing into the Atlantic and then down those flowing to the Lakes and the Mississippi.

But under the pressure of continued and rapid expansion these natural means of transportation and communication ceased to be adequate, and it became essential to provide access to large parts of the country which were distant from the coastline and the principal waterways. So canals were built to furnish a route for settlers to go West and make possible their livelihood after they got there. During the early decades of the nineteenth century, civilization spread rapidly along the rivers and into the wilderness through a spreading network of canals.

The first canal begun in this country was the Dismal Swamp Canal in Virginia. It was started in 1787 and is still the oldest canal in use in the United States. The first canal to be completed in this country was built at South Hadley, Mass., from 1792 to 1796. It was financed privately with funds raised partially by public lottery. In England and the United States this seems to have been a popular way to raise funds for canals.

The first major canal was the Erie Canal, opened to traffic from the Hudson River to Buffalo in 1825. This canal paid its own expenses and all those of New York State for many years, and millions of its surplus earnings were later used to develop the state's early railroad lines. This canal was one of the principal reasons for the growth and development of the City of New York as a major port.

Early canals in this country were built by private stock companies because the authority of the Federal Government to construct such structures as canals and highways was a bitterly contested political issue. The contract method of construction was used. Contracts were usually for short stretches, enabling many contractors to work on one canal. At

one time there were 6,000 bids for contracts to be awarded on 110 sections of the Ohio canals, varying in length from 2,000 ft to 14 miles, depending on the number of locks or other structures per section. This work attracted not only local bidders, but those who had worked in other states.

Despite floods, malaria, labor shortages, and a lack of trained engineers, contractors built more than 4,500 miles of canals in the United States from 1800 to 1850 at a cost of more than 200 million dollars. Ohio alone had a canal system almost a thousand miles in length.

By joining the inland areas with the Atlantic, the canals launched the development of the Middle West. The economic benefits were incalculable. Examples such as the following from Ohio are typical: From 1820 to 1840 population increased from 581,000 to more than 1,500,000. Property value increased from 59 million dollars in 1825 to 440 million dollars in 1850. Also the price of flour increased from \$3 to \$6 a barrel between 1826 and 1835, and the price of wheat trebled between 1820 and 1832.

The need for a comprehensive system of adequate highways was foreseen more than a hundred years before it approached a semblance of reality. There has been a complete cycle in the relation of the Federal Government to highway construction during the nation's history. First the Federal Government participated directly in the work. Then it retired and turned the work over to the states. They in turn left it to counties or other local authorities until New Jersey reversed the trend in 1891 by state aid. The current federal-aid system was established in 1916.

The importance attached to early roads is evidenced by the Act of 1802, which admitted Ohio, to the Union. This contained a provision setting aside 5 percent of the net proceeds from the sale of public land in that state for the construction of public roads leading from the navigable waters emptying into the Atlantic to Ohio's border and through the state.

One of the first roads built by the Federal Government was financed by funds resulting from the sale of public lands in Ohio, which amounted to over \$600,000 by 1806. In that year Congress appropriated \$30,000 of that sum and authorized the President to appoint a commission of three "discreet and disinterested citizens" to lay out a road running westward from Cumberland, Md. This was the beginning of the famous Cumberland Road, now U.S. 40, which had been strongly advocated in 1785 by George Washington, who as a colonel in the British Army in 1754 had widened the trail at Wills Creek, Cumberland, Md., to allow passage of his artillery.

On May 8, 1811, Henry McKinley, a Maryland contractor, signed a contract with Albert Gallatin, Secretary of the Treasury, for the first section of that road starting in Cumberland and "ending at a place on said road two miles and two hundred and forty-six perches distant." A perch was 16.5 ft, or the equivalent of a rod in length. For that he bid and was to be paid \$21.25 for each perch.

The contract contained essentially the same features as present-day contracts. It was publicly advertised and awarded to the lowest bidder; a completion date was established with a penalty for non-fulfillment; provision was made to assure payment to subcontractors and suppliers; and a schedule of partial payments to the contractor was set up.

On or near the Cumberland Road two important events in road building occurred. The first macadam surfacing in the United States was laid on an 11-mile stretch between Boonsboro and Hagerstown, Md., in 1823, and the first cast-iron bridge was built in Brownsville, Penn., in 1839, both by contractors. Construction of the Cumberland Road was supervised by the Corps of Engineers.

Another great factor in opening and developing the nation during the early 1800's was the railroads. Valuable as the canals were, there arose pressing needs for additional methods of transporting goods from the Middle West to the East across the mountains.

The first railroad to be chartered and built in the United States was the Baltimore & Ohio, the first stone of which was laid on July 14, 1828. Construction was begun on the section between Baltimore and Wheeling, which had been surveyed by the U.S. Topographical Engineers, now the Corps of Engineers.

The value of the contract method of construction was apparent to the founders of the railroad. On July 14, 1828, notice was publicly given that between August 1 and 11 proposals would be received for the grading and bridge construction on the first 26 sections from Baltimore to Ellicott's flour mill, a distance of 12 miles. Contractors were at work on all sections by October 1. The value of using contractors is indicated by the second annual report of the president, who stated in part:

> The directors are not aware that any prejudicial consequences resulted from the short notice which preceded the first letting, or that greater competition would, at that time, have caused any material change in the contract prices, which, although they are believed sufficient in every case to insure the contractors against loss, are not thought to be generally higher than has usually been paid under similar circumstances.
>
> So great, however, are the increased facilities now experienced from the improvements which have been introduced by the contractors on several sections by means of temporary railways for the removal of earth, that a great reduction of cost will accrue to the contractors. The profitable results of these improvement will be felt in subsequent contracts.

This prediction proved true, prices being lower on the next lettings, and the ingenuity of contractors reduced the cost of the entire line.

After the Civil War the new industrialism expanded throughout the country with lightning rapidity. The great fire in Chicago in 1871 accented the need for fireproof construction. The availability of steel in the middle 1880's revolutionized building construction because the steel framework could support the weight of the building, and walls no longer had to be so heavy or so thick. In the 1870's portland cement came into being, and with it came a great influence on design and construction in nearly all fields.

First Steel Skeleton Building

It was in Chicago in 1885 that the first building with a steel skeleton was built, revolutionizing building construction. It was the Home Insurance Building on the northeast corner of South La Salle and West Adams streets. Heated arguments which developed in later years as to the validity of this claim were settled in 1931 when the building was torn down. Three committees of engineers and architects investigated and agreed that it was in fact the first building to utilize skeleton construction as the basic principle of its design.

One of the greatest contributions America has made to construction is in the development and use of machinery. While the first steam shovel was built in 1837, the greatest development in machinery was in the latter part of the nineteenth century, and in the twentieth century. Horse-drawn scoops were used as

early as 1805, but the development of powerful scrapers did not come until the twentieth century.

The fresno scraper, the horse-drawn forerunner of the bulldozer, was patented in 1882. While steam tractors were used in agriculture as early as 1890, it was not until 1903 that the first crawler tractor was manufactured. The use of low-pressure heavy-duty tires for construction equipment did not come into use until the 1930's, after the contractors on the Bay Bridge in San Francisco had used airplane tires on some of their equipment.

When one reviews the past one hundred years in construction one cannot help but be impressed by the tremendous changes and the tremendous strides that have been made during that period.

While there were marvelous construction projects in the past, such as the Pyramid of Cheops, which took 30 years to build (and has, incidentally, half the volume of Boulder Dam which was built in five years); the 4,000-mile Inca highway which rises to heights of 15,000 ft; the Chinese Wall and hundreds of others, they are particularly remarkable for having been built almost entirely by hand.

A hundred years ago most American construction was by hand, and aside from some use of cast iron or wrought iron, little change or improvement had been made over the methods of the past.

Today, such challenges as the unprecedented dams, irrigation, flood control, and power projects of the West are taken in its stride by the construction industry. It is worthy of note that in just one phase of the industry, the building of highways, construction contracts awarded by state highway departments throughout the country in one year, 1951, were for a total of 54,650 miles.

The Early Contractor

There is evidence that shortly after the settlement of some of the earliest American colonies it was the practice to have construction performed by contractors with written contracts. When buildings were primarily of wood, or brick and stone, the contractor generally was the master mason or master carpenter.

But when structures became more complex; when steel, concrete, and other new materials came into use; when plumbing, heating, lighting, and later, elevators, were incorporated in buildings, and when new machinery came into use, it was no longer possible to have all the work under the direction of the mason or carpenter.

When the construction industry was undergoing its period of fast growth and change after the Civil War, there were apparently also growing pains in its organization. It became necessary to develop some kind of organization that could combine and coordinate the various skills required for the new features of building.

While more research needs to be done on this turning point in the history of the construction industry, it appears that somewhere during the middle 1880's the general contractor, such as we know him and his organization today, first became recognizable.

Before the bona-fide general contracting firms were organized to take complete and undivided responsibility for the execution of a project, it appears that sometimes the architect or engineer who designed the project also coordinated the work of the various individual contractors and supervised their operations. Sometimes this function apparently was fulfilled by the owner, or a representative of the owner, such as the Corps of Engineers in the case of government construction.

Early contracts were much the same as now, calling for guaranteed quality, penalties for delays or failure to complete the work; assurance that suppliers, subcontractors, and labor would be paid; and periodic payments with a percentage retained for payment on completion and acceptance. Most public works contracts seem to have been awarded after competitive bidding, as is the custom today, and they were at firm prices or so much per unit.

In private work, there appears to have been some use of contracts on the basis of cost plus 10 percent, but that type of contract has been almost entirely replaced by the cost-plus-a-fixed-fee contract.

There is considerable evidence that, in earlier days, work privately financed was often undertaken and completed without formal contract; that much of it proceeded on the basis of a verbal understanding or of letters.

Construction Industry Today

A good way of making evident the development which has taken place in the construction industry in the United States is to glance at its present activities. During 1951 it was the largest single industry in the United States. The volume of new construction put in place was more than 31 billion dollars, according to the revised estimates of the Departments of Commerce and Labor. In addition, approximately 9 billion dollars worth of maintenance and repair operations were performed to bring the total volume of construction activity to 40 billion dollars. This exceeded the total value of agricultural production, which normally has been the greatest industry in the nation. Nearly one dollar in every eight created in end products and services in the United States in 1951 was a construction dollar.

Throughout the year an average of $2^1/_4$ million men were employed each month by general contractors and subcontractors at the sites of construction projects. For each man working at the site, from two to four other jobs were created elsewhere in the production or transportation of materials and in the performance of services for the industry.

Of this construction, more than 21 billion dollars was privately financed, and more than 9 billion dollars was invested in public funds. Of the private funds invested, almost 11 billion dollars went into residential construction; more than 5 billion dollars into non-residential building for industrial, commercial, religious, educational, health, and other institutional purposes; and more than 3 billion dollars into public utilities.

Of the public funds, more than 3 billion dollars was invested for educational and other public institutions; approximately $2^1/_2$ billion dollars for highways; almost 1 billion dollars for conservation and development of resources; and more than 1 billion dollars for military construction.

During the first six months of 1952, another record of nearly 15 billion dollars in new construction was established. There is the possibility that if materials are available during the remainder of the year, another annual record of more than 40 billion dollars in construction will be established. The impetus for a large volume of construction this year is from military, industrial, and public utility construction.

These figures on construction activity are too big for most of us to comprehend readily. But they do clearly indicate that the construction industry is performing a tremendous amount of work for the nation and all of its communities.

Construction now is not only a huge industry, but its work is fundamental to the growth and development of the nation and its communities, and it plays a part in

practically every aspect of our civilized life.

In the AGC we have used the phrase, "America progresses through construction." We believe that to be true. And we believe also that the role of the construction man, like that of the engineer, is little understood by the general public.

One of the reasons the United States has become a great nation is that there has been not only the genius, the foresight, and the courage to develop new industries and better ways of developing our resources but also a progressive and ever-developing construction industry which could fulfill the nation's needs for physical facilities—an industry which has striven to retain its flexibility.

Essentially it must be broadly dispersed in all its phases to meet local needs promptly. Through joint ventures the construction industry has learned to put its units together in any combination necessary to do the job. It must be present in all its phases at all times in every community if the full function of the industry is to be performed

While we do not have accurate statistics on the volume of construction in the early days of the nation, a brief reading of history will indicate what a tremendous role in the country's growth has been played by the construction industry in building for many purposes: industrial, conservation and development, transportation, commercial, residential, community, governmental, health, educational and institutional, national defense, civil defense, and disasters. The industry has also kept pace in providing facilities for recent developments in such fields as aviation, electronics, and atomic energy.

These are some of the reasons why all those men and women who are a part of the construction industry in one capacity or another can and do take pride in their accomplishments.

New construction is probably the most spectacular function of the construction industry, but the industry has many other jobs. The physical facilities of the nation, which were built by the industry, also need to be maintained, repaired, and remodeled from time to time to fit new conditions, and the industry must do these things also if it is to be most useful. Nearly a quarter of the industry's work is for this purpose.

When disasters strike, such as earthquakes, tornadoes, explosions, floods, and heavy snows, the damage must be repaired, and water, light, gas, and other facilities must be restored to operation. This is another task of the construction industry. On occasions such as the explosion at Texas City, the tremendous snows in the Great Plains states, the floods in the Kansas City area, and other emergencies, contractors and others in the industry have mobilized immediately in cooperation with civic authorities and started their workmen and their machines to work clearing debris and repairing damage. Some time later they took the time to consider what should be the proper compensation.

The AGC has cooperated with the Federal Civil Defense Administration and has submitted a comprehensive plan on how the facilities of the industry can best be mobilized in the event of an emergency, and many other organizations in the industry have done likewise.

In 1947 the Army initiated its Affiliation Program, by which reserve units in which each man is specially fitted for his military assigment by his civilian work, are recruited and trained for call to active duty when necessary. The AGC was asked to cooperate with the Corps of Engineers in sponsoring and recruiting reserve construction units. So far 76 units have been sponsored and 21 have been called to active duty. Two have been engaged in Korea, where they have performed the outstanding engineering feats of that campaign. Many engineers, architects, and others in the industry have joined these units. There are also two units in the European Theater.

These activities of the construction industry serve to emphasize why the industry is so fundamental to the welfare of the nation and its communities

Construction for National Defense

Construction is as important to the national defense as it is to the peacetime development and progress of the nation. For World War II the construction industry completed work valued at more than 49 billion dollars. This work constituted at that time the world's greatest single construction program, and it represented an expenditure of approximately $400 for each man, woman, and child in the country. The war was actually won by fighting men, but they had to be supported by the products and services of American industry. One of those industries was construction.

Camps virtually as complete as cities had to be set up before men could be trained and sent overseas. Factories had to be constructed before airplanes, tanks, guns, munitions, and other weapons of war could be produced in quantities sufficient to overwhelm the enemy. Yards had to be built before a bridge of ships and a seven-ocean navy could be launched. Bases had to be constructed before attacks could be directed at the enemy.

It was necessary that this construction work be completed before many other parts of the war program could be undertaken. Because of this, construction was the first major industry to attain large-scale defense and war production. By the time of Pearl Harbor it was converted 75 percent to war work, and at one time more men were mobilized on construction work for the Army than were in the Army itself.

Had construction failed in any part, other phases of the war effort would have been hampered, perhaps disastrously. But there were no bottlenecks in construction; the work was completed at unprecedented speed. The speed cost money, but by helping to speed the end of the war it saved lives.

As members of the armed services, construction men, with their methods and machinery, helped to develop the capacity for building airfields, docks, railroads, pipelines, and for moving millions of tons of supplies at speeds never before attained in military operation. The nation's capacity to construct both at home and in combat areas was such that the wartime Chief of Army Engineers was able to report:

> By the war's end it was evident that American construction capacity was the one factor of American strength which our enemies most consistently underestimated. It was the one element of our strength for which they had no basis for comparison. They had seen nothing like it.

Should there be another war and the United States be subjected to bombings or other catastrophes, the construction industry will be immediately available to clear debris and restore essential facilities to use in minimum time. There is no way in which such work can be done except by the construction industry.

Construction Industry Plays Vital Role

The construction industry throughout the history of the United States has had, still has, and always will have a tremendously important part in the development, growth, and progress of the nation and its communities, and will serve as a medium

(*Continued on page 252*)

ROBERT F. BLANKS, M. ASCE

Vice-President and General Manager

Great Western Aggregates, Inc., Denver, Colo.

Good concrete depends on good aggregate

A little over one hundred years ago, in the April 1848 issue of the *Scientific American*, there appeared the following statement:

> **"Concrete.—This is the name of a mass of sand and small stones cemented together by lime, or some other cement. . . . A good plan is to mix the cement dry with the other materials and then throw water over them to make a perfect mixture by turning over."**

From this quotation we learn that at the time the American Society of Civil Engineers was founded, a batching plant consisted of a shovel and perhaps a wheelbarrow, while a mixing plant was simply a shovel in the hands of a workman. Concrete as we now know it did not exist because but little natural cement and no portland cement was being produced in the United States, and about the only cementing medium available was lime. Sand and gravel were used as found, and stone was probably prepared by the hammer and rock-pile method. The development from these simple beginnings to our present-day aggregate processing, batching and mixing plants—veritable houses of magic—is truly typical of the engineering progress that has been made in the construction field during the past one hundred years.

Excellent descriptions of concreting plants can be found in numerous technical publications. Therefore, it is not the purpose of this discussion to present such descriptions but rather to discuss the reasons for such plants and what they are expected to accomplish.

According to available records, the first concrete mixers came into use about 1857 and consisted simply of revolving cubicles or cylinders mounted on a diagonal axis. Aside from a tremendous increase in size range and improved efficiency in power requirements, our present-day mixers represent an unusually small improvement, as far as mixing action is concerned, over the early-day models. For some reason we have been unable to devise machines that will provide the kneading and folding action generally recognized as being most desirable for the mixing of concrete. The action in most mixers now available is more like that of a ball mill, and there is considerable attrition with attendant modification of the particle grading curve, particularly in the finer sizes. This in turn means increased water and cement requirements and greater drying shrinkage.

It is true that in very recent years, we have learned that the blading arrangement in drum mixers is a factor in obtaining efficient mixing, but to realize any semblance of efficiency, within reasonable mixing periods, the sequence of batching the various ingredients of the mix must be carefully controlled. In other words, we depend in no small degree on the batching plant to accomplish the concrete mixing. The almost unbelievable improvement in aggregate processing and concrete batching equipment is in sharp contrast to the lack of advancement in the mixer field.

In the early years of concrete history, batch measurement of ingredient materials, if performed at all, was accomplished by volume in various types of boxes or containers. Most frequently it was done by counting shovelsfull. Volume batching was not satisfactory because a cubic yard or foot of granular material is an indefinite quantity, depending upon its condition, such as "dry-loose," "moist loose," "dry-rodded," and "compacted." As the weight of any concrete ingredient is directly related, by specific gravity, to the solid space which it occupies in the concrete, the weight system of batching is logical, flexible and simple but accurate, and requires adjustment only for the moisture contents of the aggregate fractions. In professional concrete construction, weigh batching is now employed exclusively. The desirability of weigh batching was recognized as early as 1868, although it was not until well after the turn of the century that the practice came into general use.

Aggregate Processing Objectives

In processing aggregates various beneficiating operations are performed on the raw materials to improve their quality, improve their gradation, improve their uniformity, provide materials that can be adequately controlled, and make possible the most economical utilization of the available materials. The beneficiating operations may include any combination of the following processes:

A. Quality Improvement
   1. Removal of organic and other contaminating materials
   2. Elimination of soft or structurally unsound materials
   3. Removal of weak adherent coatings
   4. Improvement of particle shape
   5. Reduction of saturation of coarse aggregate

B. Gradation Improvement
   1. Reduction of oversize or excess sizes of materials to augment the supply of other sizes or build up deficient sizes
   2. Control of sand gradings within narrow limits of the selected average
   3. Removal of excess fines or other sizes

C. Uniformity Control
   1. Separation of sand from gravel
   2. Separation of coarse aggregate into various size fractions
   3. Dewatering to control moisture content
   4. Prevention of segregation in finished aggregates
   5. Prevention of attrition in finished aggregates
   6. Reduction in temperature of finished aggregates
   7. Reduction of oversize and undersize fractions in coarse aggregates to a minimum

D. Economics
   1. Manufacture of stone and crushed aggregate
   2. Dust collection
   3. Reclamation of heavy minerals
   4. Reduction of oversize or excess sizes of materials to augment supply of other sizes or build up deficient sizes
   5. Reduction of cement requirements by improving particle shape, and controlling sand gradings within narrow limits of the selected average

In considering the above objectives and operations in detail, no sharp lines of demarcation can be drawn, as many of the processes spread across more than one of the broad objective classifications. In particular, the economics of any of the operations should not be overlooked, that is, it is necessary to inquire whether the end result justifies the cost. In the case of those operative items under quality improvement, and some others, the economic factor is somewhat intangible because the improvement in the end product—the concrete—cannot always be evaluated.

Improving Concrete Quality

Dirty aggregates cannot be tolerated in making quality concrete; therefore washing to remove organic material, such as clay and mud, is usually about the first operation performed in processing natural aggregates. This is accomplished coincidentally with some other operation such as screening, scrubbing, or abrading. The important aims in washing are to obtain clean, coarse aggregate particles, free of adherent coatings of fine materials which impair bonding with the cement matrix, and to eliminate dirt and organics from sand, at the same time retaining sufficient quantities of the finer sizes passing the No. 50 and 100 mesh sieves. Proper proportions of these sizes are essential to workable, cohesive, nonsegregating concrete mixes with a low water requirement.

Structurally unsound or soft materials, coal, and poorly bonded coatings can be broken up by log washers or other available types of abrading equipment and removed in the washing operation. In one case of record, increased concrete strengths at 28 days—by as much as 1,000 psi—resulted from such beneficiation of the particular river sand and gravel involved. Heavy media separation is coming into wider use for removing undesirable constituents from coarse aggregate. The process is adaptable to material ranging in size from $^1/_8$ in. to 8 in. Materials can be handled which range in specific gravity from 1.25 to 3.75, and separations effected within ± 0.01.

Particle shape is an important factor in concrete workability and cement and water requirements. Typical sand particles in aggregates actually used on two similar projects are shown in accompanying twin photographs. One is well rounded, the other, harsh and angular. For concrete with $1^1/_2$-in. maximum size aggregate and a water-cement ratio of 0.50, by weight, using the angular material, 300 lb of water and 6.39 sacks of cement per cu yd of concrete were required. Using the rounded aggregate, the same factors were 220 lb of water and 4.69 sacks of cement per cu yd of concrete. It was established that this difference in concrete making qualities was due to differences in particle shape and gradation. The latter concrete, in addition to being of higher quality by reason of its lower water requirement, saved 1.7 sacks of cement per cu yd, which would more than pay for an effective abrading operation to improve the characteristics of the angular aggregate.

The objections to using aggregate having poorly bonded coatings are obvious. In addition, some coating materials are chemically reactive in concrete and therefore should be removed or the aggregate should not be used.

Tests have proved that some porous river gravels which have become supersaturated through ages of inundation produce concrete that is highly susceptible to disintegration by freezing and thawing unless they are partly dried prior to use.

Gradation Improvement Important

Probably no other physical characteristic of aggregate has such an important effect on the water requirement and workability of a fresh concrete mixture as gradation, or particle-size distribution. These factors in turn profoundly influence a large number of other important concrete properties. For any given aggregate there are a number of grading combinations which will be about equally suitable on the basis of workability and cement and water requirements, provided reasonable limits are observed and a specified degree of uniformity of grading within these limits is maintained.

The average grading to aim for with any given aggregate depends on three factors: (1) the results of trial concrete tests which will show the most desirable range; (2) the average pit-run grading or, in the case of manufactured aggregate, the crushing characteristics; and (3) the economics of the case, involving grading correction costs, cement requirements, and concrete handling and finishing costs. When the average sand grading standard has once been established, this average should be maintained within a fineness modulus variation of not more than ± 0.10. Normally, sufficiently wide variations in coarse aggregate fractions can be tolerated to absorb any reasonable fluctuations in pit-run or crusher-run yields. Pea gravel, and particularly the No. 4 to $^3/_8$-in. size, is the most critical, as this fraction seems to have the greatest influence on bridging between the aggregate particles.

Whether oversize material is wasted or crushed to augment the usable sizes is largely a matter of economics, which should take into account the cost of wasting versus the cost of crushing, plus the cost of increased cement content resulting from the addition of the crushed material to the finished coarse aggregate. Similarly, what should be done with excess size fractions after they are removed is a matter of economics, together with the pit-run or crusher-run balance between the proportions of sand and the various size fractions of coarse aggregate.

Uniform sand grading within narrow limits of the selected average is essential to the production of uniform concrete. This can be accomplished very effectively by hydraulic classification, mechanical classification, or a combination of both. The process

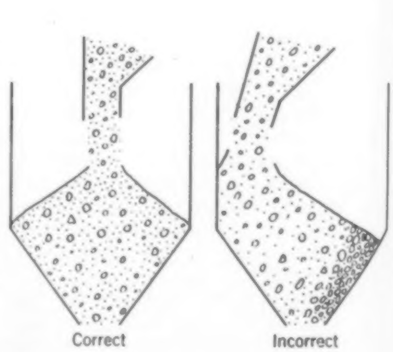


FIG. 1. Correct method of delivering aggregate to bin reduces segregation and promotes uniformity of concrete. Bin should have bottom sloping 50 deg from horizontal on all sides to outlet, with all corners rounded. Flat bin bottom or slopes meeting at sharp corners produce uneven flow.

involves roughly separating the pit-run sand into fine, medium, coarse, and sometimes intermediate gradings, which can be recombined in proportions that will maintain the desired gradings. Where complete classification is not economically practicable, sand gradings can be controlled by removing excess sizes by various arrangements of riffles, slots, screens, traps, baffles, or such, in the washing process.

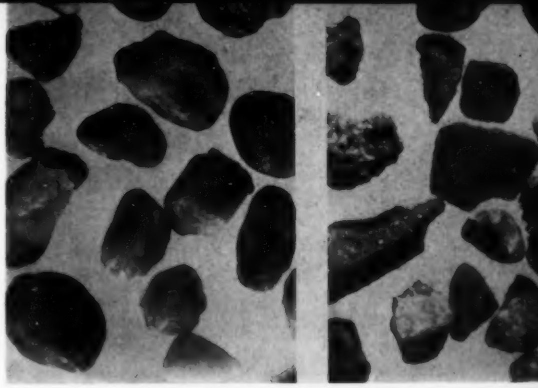
Maintaining Uniformity Control

The production of uniform concrete from batch to batch would not be much of a problem if exactly the same number and sizes of solid particles could be put into each batch. This is obviously impracticable, but it is important to exercise every precaution to see that aggregates arrive at the mixer as uniformly sized and graded, and as uniform in moisture content, as is economically feasible. Reduction in cement and water contents of concrete, with a resulting improvement in quality of as much as 20 percent, can be effected by uniformity control of aggregates. It is particularly important that sand be stockpiled a sufficient period before use to permit drainage to a stabilized moisture content. This can be done by drawing from one end of the stockpile while filling at the other.

If coarse aggregates have been cleanly separated into sized fractions, and sand has been effectively classified and recombined to a uniform finished product with stabilized moisture content, then the delivery of uniform aggregates to the mixer is largely a matter of storing and handling in a manner which will retain their uniformity. Any handling or transfer performed on coarse aggregates will cause some segregation and breakage. Consequently it is essential that the number of such operations be held to the minimum, and every precaution taken to minimize segregation, breakage, and contamination. Figures 1 and 2 show correct and incorrect methods of handling aggregates and avoiding segregation and breakage.

Most aggregate materials are somewhat brittle and break down from impact or from attrition. Repeated moving of equipment, such as trucks, bulldozers, and tractors over finished aggregates should be avoided. Coarse sizes should be dropped to stockpiles through rock ladders to reduce rock breakage and segregation. Aggregates should not be discharged from the sloping ends of chutes, but should be baffled to break the force of discharge and fall, and to direct their transfer in a vertical direction. Scalp-

Shape and surface texture of aggregate particles have important bearing on quality of concrete. Rough, angular types at right will require considerably more cement and water than smooth, rounded ones at left.



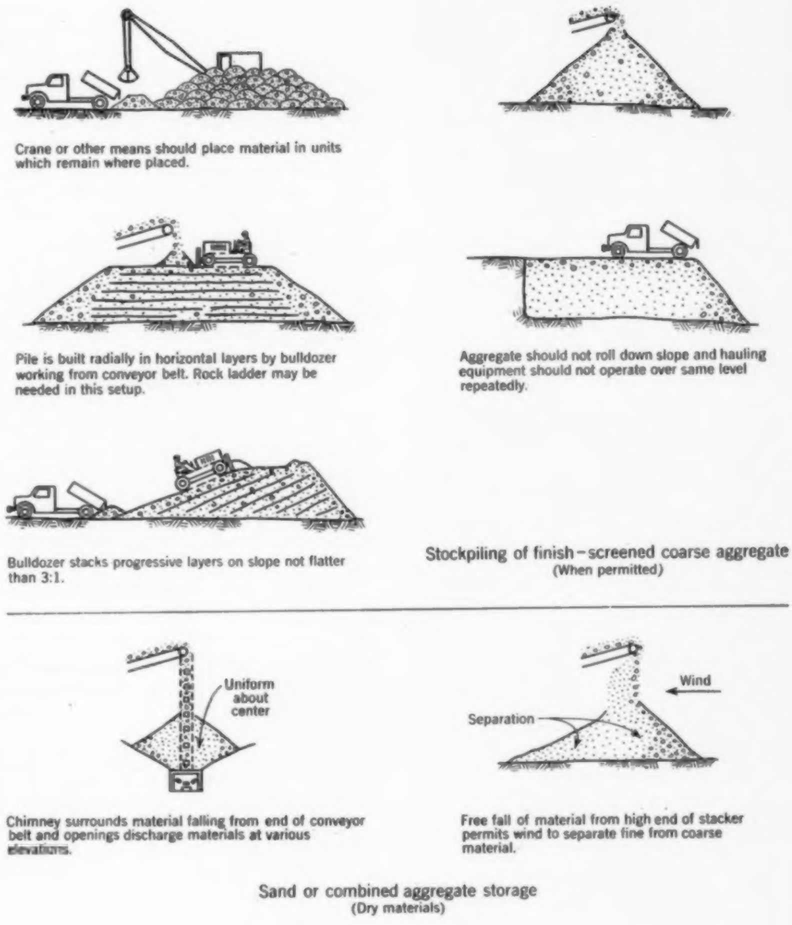


FIG. 2. Incorrect methods of stockpiling aggregates cause segregation and breakage.

Improper stockpiling (see Fig. 2) causes excessive undersize in coarse aggregate fractions, with resulting lack of uniformity of concrete.

ing screens, with appropriate size openings, at transfer points are a cheap and effective means of removing undersize materials caused by breakage. Proper design of the hopper bottoms of bins, and the sequence of stockpiling and reclaiming operations, can also do much to reduce segregation. Efficient feeder machines also may be used to advantage to reduce segregation.

The most effective means of obtaining uniformity in coarse aggregate fractions is to perform the final or finish screening operation directly above the batching plant bins. Experience and records on many jobs have proved that such procedure not only results in increased quality of concrete, but saves time and money for both owner and contractor, because: (1) it produces concrete of uniform consistency and workability thereby reducing handling, placing and finishing costs; (2) it reduces or eliminates wasted and rejected aggregates; and (3) it reduces the cost of processing and handling aggregates prior to batching.

The objective in finish screening at the batching plant is to reduce to a minimum the significant undersize in the coarse aggregate fractions. Significant undersize is defined as the material passing a test screen with openings one-sixth smaller than the nominal minimum size of the aggregate fraction. For example, the significant undersize in the $^3/_4$ to $1^1/_2$-in. aggregate fraction would be material passing the $^5/_8$-in screen.

The cost of installing vibrating finish screens above batching-plant bins is quite nominal, and they can be operated coincidentally with the batching plant. Horizontal screens are most satisfactory, because of the tendency of operators to overload sloping screens and cause the undersize aggregates to ricochet across the screens rather than to pass through them.

Table I shows a comparison of the significant undersize in aggregates as batched for a number of cases where the aggregates were stockpiled and rehandled, and for other cases where the aggregates were finish screened at the batching plant.

Holding Down Concrete Temperature

In hot, arid climates, it is important that the temperature of fresh concrete be held to a practicable minimum. One way of accomplishing this end is to play light sprays of cool water over coarse aggregate stockpiles. The evaporation effect reduces the temperature of the aggregates appreciably.

Since the economics of the various objectives and operations in aggregate processing has been discussed along with the various factors involved, little more need be said on this subject. It should be emphasized that the types of crusher equipment employed in producing manufactured sand and crushed aggregate have an important effect on the shape of the individual aggregate particles. Therefore such equipment should be selected with care to best fit the particular material involved.*

Batching and Mixing

The purpose of batching plants, of course, is to proportion, accurately, predetermined quantities of the various ingredients of the mix so that each successive batch will have the same composition, within practical limits. Depending on the size and importance of the concrete work, the batching plant may range from merely a wheelbarrow scale to a complicated, automatically controlled, self-recording storage, weighing and dispensing plant with push-button operation. Where the work is scattered, a central batching plant is most desirable. In such cases the dry batches may be transported in compartmented trucks to a job-site mixer, mixed at the plant, and transported in agitator trucks to the work, or mixed in transit. Transit mixing is the most difficult to control, as will be brought out later.

Granular materials should be proportioned only by weight, but volumetric tanks, meters or dispensing units are just as effective as weighing for water and liquid admixtures such as air-entraining agents and calcium chloride solutions. When ice is used to reduce the temperature of fresh concrete, it should be batched by weight. Scales should be of reliable and rugged construction and should be properly maintained; they should be calibrated and adjusted at regular intervals. Liquid meters must also be checked regularly. Water batching tanks should be arranged so that the quantity can be changed readily and the predetermined amount of water controlled by an overflow arrangement.

The moisture content of aggregates, particularly sand, and the specific gravity of aggregates vary from time to time. Tests should be made regularly so that proper adjustment of the weights and measures can be made. This requires convenient scale and dispenser adjustment. The precise amount of water to be added to any given batch should be controlled by the operator by observing the fresh concrete in the mixer and bringing it to a predetermined slump or consistency. Mixers equipped with consistency meters facilitate this item of control. In any case, it is a wise precaution to have automatic cutoffs and overflows so arranged that not more than a permissible maximum amount of liquid can be added to any one batch.

Weigh batchers may be either the cumulative weighing or the individual weighing type, the latter being preferable because of greater flexibility for controlling the mixing of the various sizes of aggregate and cement as they are batched. Batchers should be equipped with large, full-reading springless dials, mounted so they are readily visible to the operator. Over-and-under indicators are satisfactory on wheelbarrow scales. The transfer of materials from storage bins to batcher, to transfer belts or to mixer, should be appropriately baffled so that the fall will be vertical to minimize segregation.

For large jobs or for permanent plant installations, automatically controlled batching plants are recommended because they minimize the human element, reduce errors in batching, and reduce labor requirements. Graphic recorders serve not only as a permanent recording of plant performance and output but provide the operator with an instantaneous warning of inconsistent or improper plant functioning. Equipment is available which will re-

TABLE I. Reduction of Undersize in Aggregates by Finish Screening at Batching Plant

Plant Designation	Percent Significant Undersize as Batched (Average)	
	No. 4 to $^3/_4$"	$^3/_4$" to $1^1/_2$"
Aggregates stockpiled and rehandled:		
Plant No. 1	10.6	15.4
Plant No. 2	6.5	8.0
Plant No. 3	7.5	6.0
Plant No. 4	3.3	8.4
Plant No. 5	5.0	5.0
Plant No. 6	7.0	4.0
Plant No. 7	8.0	8.0
Plant No. 8	2.0	5.0
Average	6.2	7.5
Aggregates finish screened at batching plant:		
Plant A	1.0	3.0
Plant B	2.0	4.0
Plant C	2.0	1.0
Plant D	1.7	4.2
Plant E	0.0	1.2
Flant F	2.2	3.4
Plant G	3.5	1.0
Plant H	4.0	3.0
Plant I	3.0	4.0
Plant J	0.8	0.8
Plant K	3.1	2.4
Average	2.1	2.5

cord for each batch the individual weights of each ingredient material, and also time, temperature and consistency.

The proper design and installation of batching plants to provide for flexibility in operation, convenience of maintenance, and easy means for sampling materials are of utmost importance to insure trouble-free production of uniform concrete. Aggregate bins should be designed for central charging and discharging, with hopper bottoms sloping at 45 deg and with rounded rather than square corners. The importance of the proper arrangement of baffles and spouts to insure vertical fall at transfer points is again emphasized. The sole objective in arranging for the handling, storage and transfer of aggregate materials through a batching plant should be the reduction of segregation to the practicable minimum.

Tilting mixers are more efficient than non-tilting models, because they can be discharged more rapidly and completely and with less segregation. Also, they are easier to clean and more accessible for observation of the mixture during the mixing process. The effectiveness of the mixing action is a function of the charging sequence, the shape of the mixer drum, and the shape and arrangement of the blades. The uniformity of the mortar throughout a batch of concrete is a reasonably reliable measure of the thoroughness of mixing. Mortar uniformity tests should be made as required as a guide to the best blading arrangement, to fix the length of the mixing period, and to establish the need for blade replacement or repair. Instances are on record where the efficiency of mixers has been improved 50 percent or more by blade rearrangement, usually toward the simplification side.

Mixers should be equipped with timing devices to insure the required mixing period for each batch, which will vary from $1^1/_2$ min for smaller models, to 3 min for 6-cu yd machines. Overcharging beyond rated capacities should be avoided in the interests of efficiency, uniformity, and elimination of wasted materials. Mixers should be kept clean at all times and, in particular, coatings of hardened mortar on blades should not be permitted. Batch counters are an effective means of recording concrete production.

The method of discharging mixed concrete should be such that segregation is held to a minimum. Here, as in the case of aggregates, the correct arrangement of chutes and baffles to direct the transfer in a vertical direction will prove the most effective. At the start of mixing operations, the machine should be primed by wetting the inside of the drum and then adding a little excess cement and sand to the first batch. The mixer should be charged by first adding about 10 percent of the required water, followed by 80 percent of the water simultaneously with the cement, sand and coarse aggregate, all as completely intermingled as practicable. The remaining ± 10 percent of water should be used by the operator as tempering water to bring the batch to the desired consistency. Tempering to obtain a specified slump is a delicate operation and requires skill and care on the part of the operator. A change in water content of only about 3 percent is sufficient to cause a change of 1 in. in slump.

Truck mixers are very popular, to deliver both from ready-mix plants and from on-the-job construction plants where the work is scattered. Much more care and control of all operations is required to obtain concrete of uniform proportions and consistency with minimum water content with truck mixers than with stationary mixers. However, acceptable results can be obtained if certain precautions are exercised and correct

(*Continued on page 261*)

Rock ladders provide effective means of stockpiling coarse aggregates without excessive breakage and segregation.

Use of scalping screens at transfer points is cheap and effective means of removing undersize material from aggregates.

Finish screening directly above batching-plant bins is best way of insuring uniformly graded aggregates at mixer. Horizontal vibrating screens (left view) are generally most suitable for such finish screening.

EDWARD R. HIGGINS, J. M. ASCE

Engineer, The Surety Association of America, New York, N.Y.

Suretyship — a stabilizing factor in

Relation between surety company and contractor is close. Combination of dependable surety and qualified contractor makes team that can bid and perform under most unusual conditions. Photo courtesy Eye Catchers, Inc.

Among large projects made possible by surety bonding is Chesapeake Bay Bridge. Suretyship gives owner same grade of protection financially which good specifications ensure structurally.

When a scientist was asked recently if he were concerned about the possibility of the earth's destruction from a man-made atomic explosion, he casually shrugged and said, "So what? It isn't as though it were a major planet!"

The unusualness of this man's reply lies in his perspective, his sense of values, or as engineers would phrase it, his "scale of observation." It is obvious to all of us, for example, that a car looks different when seen from the street than it does when seen from a skyscraper; it is just as true, but not as obvious, that what seems like a straight line to us would seem, because of the rotation of the earth, like a corkscrew to a Martian. If this sounds strange, it is only because we are not used to thinking on so broad a scale. Yet that is precisely the function of centennials, for they give us a chance to view ourselves through a wide-angle lens and without that accuracy of detail which defeats its purpose.

Using such a scale of observation, let us look at the role that suretyship has played in the building of America.

From the standpoint of history, suretyship, while exceedingly modern in its present applications, is perhaps the oldest type of business protection known to man. Solomon warned, "He that is surety for a stranger shall smart for it," and "He is devoid of sense who becomes surety for another." There were no bonds on the Pyramids, as far as we know, but maybe there should have been if Kipling was right when he wrote:

> Who shall doubt "the secret hid
> Under Cheops' pyramid"
> Was that the contractor did
> Cheops out of several millions?

Many contracts in ancient Rome were bonded, and one of them in 106 B.C. provided that "one half shall be paid down as soon as the bonds secured by the real estate shall have been executed, the other half upon completion and acceptance of the work." If modern engineers would be that generous I am sure that contractors would be hearty in their approbation and lavish in their praise of contract bonds.

In England, the Magna Carta, the great milestone on the road to human freedom, was bonded, and Shakespeare also in *The Merchant of Venice* uses the vicissitudes of those who become surety as the theme of one of his most absorbing dramas. It was also in London, during the middle of the last century, that corporate suretyship was established, in a place inauspiciously called the Tavern of the Devil and St. Dunstan. Since that time, corporate suretyship has survived its growing pains and taken its place among the important businesses of the country. And while not of American origin, it is really an American phenomenon, since its major growth and development as an industry have taken place in this country.

What the Surety Does

Today, surety companies undertake to make good the losses caused by persons who have obligated themselves to do certain things but have failed to meet their obligations by reasons of error, fraud or fate. Their basic purpose is the elimination of financial risk. In the construction field, contract bonds make it possible for a contractor to provide the engineer and the owner with a responsible guarantee that he will satisfactorily complete the project at his price,

Suretyship instigated and made possible joint venture as known today. Joint venturing came into its own for what was probably greatest single project undertaken in history of the country, Hoover Dam. For this project bond larger than any previously written was furnished to back Six Companies Inc.

r in onstruction industry

and pay his bills notwithstanding the fact that a number of other contractors have disagreed with his judgment.

A contract bond then, is simply an I.O.U. with an "if" in it. In the simplest language, it says "I (Mr. Surety) promise to pay you (Mr. Owner) up to the amount of this I.O.U., for any loss you may sustain if my friend (Mr. Contractor) should not perform his contract with you. If he performs, I owe you nothing."

The most important types of bonds used on construction projects are the bid, performance and payment bonds. The bid bond guarantees that the bid is made in good faith, that the bidder will enter into a contract if his proposal is accepted, and that he will also furnish performance and payment bonds. The performance bond usually covers whatever obligation the contractor assumes in his contract. The payment bond guarantees that the contractor will pay for labor and material. Sometimes the obligation to pay for labor and materials is included in the performance bond itself. This type of bond is called a combined performance and payment bond and such a form was used by the Federal Government until 1938. Because of certain difficulties under a single bond, such as priorities of the owner, the Miller Act was then enacted which provides for the superior dual system of separate performance and payment bonds that is in use today.

The Three C's

Obviously, before a contractor can obtain a bond he must be qualified. The science and art of determining a contractor's qualifications for a bond is called underwriting and the men who do it are called underwriters. In determining a contractor's ability to swing a particular job, all underwriters apply the so-called three C's of credit, namely, Character, Capacity and Capital.

Character means that the contractor "must consistently and persistently comply with the spirit as well as the letter of his contracts. He must have business experience and handle every transaction with fairness and honor." Character is the best collateral; money cannot buy it; it is the keystone of the underwriting arch.

Capacity means that the contractor "must possess the necessary technical knowledge and practical experience as applied to his particular form or group of undertakings to enable him to carry them to completion in a workmanlike and economical manner."

Capital means that the contractor "must possess cash or credit to meet all his commitments, also the equipment and organization for the satisfactory performance and completion of his undertakings."

These excellent definitions, by the way, will not be found in any surety textbooks. They happen to have been chosen verbatim from a brochure entitled "The Organization and Work of the Associated General Contractors of America," only there they appear as definitions of "skill," "integrity" and "responsibility." Such interdefinability is a perfect illustration of the natural affinity of the surety and construction industries and of their similarity of aim and purpose.

Of course, inherent in these three "C's" of credit is a fourth "C" which is becoming more important every day, namely, the "C" of Changing Conditions. The economic, social,

judicial and political developments of the times have a profound effect on such a basic industry as construction, and no prediction of success for a project could be complete without a careful estimate of these increasingly fluctuating factors.

To put it in a nutshell, the essential elements of any *successful* construction project are Men, Money, Method and Material, the so-called four "M's" of construction. Strangely enough, however, these same elements are present in *unsuccessful* projects. The difference, of course, lies in the skill, integrity, and responsibility of the builder, and the four "C's" of underwriting separate the men from the boys by evaluating these qualities.

The Contract Bond Agent

Complementing the underwriter and holding a position of importance is the contract bond agent. The agent is an adviser to contractors and owners but he is more commonly called a producer, and he really does produce. Quite often, before the contractor even learns of the project, the producer is visualizing its potentialities and difficulties. After the contract is awarded, the producer continues to act in an advisory capacity and as a coordinator between the owner, the contractor, and the surety. He frequently finds sources of labor and expedites deliveries of material, aides in obtaining additional financing, assists in resolving the temperaments of individuals and groups, and performs a host of other valuable services.

To accomplish this, his contacts must be far flung and his talents manifold. Part contractor, part lawyer, part financier, and part detective, the producer must likewise be an able advocate, for without leading a contractor beyond his depth, he must satisfy the underwriter of his client's ability to perform those contracts which represent a steady, healthy development of contractual capacity.

Since no underwriter or agent is a prophet, or a son of a prophet, however, and despite careful underwriting, it is a painful fact that losses do occur and a bond meets its ultimate test when a claim is made.

At one time, engineers looked upon a contract bond as simply an invitation to a lawsuit. Partly, they were right, for in the formative years of corporate suretyship there was little or no experience available, the competition rate-wise was chaotic, and many surety companies had to decline liability on technical grounds in order to remain solvent. Furthermore, the law at that time was mostly in the surety's favor. This was due to the personal origin of suretyship, because generally there was little or no consideration or premium for the personal promise of an individual to be surety and hence the courts strictly construed the obligation. With the growth of compensated surety companies, acquired experience, and improvement in rating techniques, the courts have liberally construed the surety bond and the companies bend every effort to make claim adjustments promptly and fairly.

The basic purpose of a bond, then, is the elimination of risk to the owner. In addition to providing this indemnity for loss, however, the ever growing employment of contract bonds and the development of broader forms and new techniques have led to surprisingly valuable by-products of a bonded competitive system. Indeed, it is not untrue to say that even if there were no defaults, bonds would more than pay their own way.

The most outstanding by-product of a bonded system is the speedy, economic and preferential effect of the payment bond upon the flow of labor and material. The payment bond has these effects because contractors are engaged in a business made more than normally hazardous by the vagaries of the elements, the physical problems of subsurface conditions, and numerous other problems. Their subcontractors and suppliers, like all business men, must provide for business risks in the price they charge for their work or services. If they are exposed to abnormal credit risks they have the choice of: (1) refraining from accepting the business—which benefits nobody; (2) charging for the extra risks—which results in a greater cost to the owner; or (3) seeking a guarantee of payment such as the payment bond—which will permit them to speed their credit investigations, eliminate their credit risk charge, and make preferred deliveries to bonded rather than to unbonded work.

It is a matter of public record that many large and responsible general contractors and subcontractors are favoring work on which payment bonds are required. On such work, these general contractors are securing better prices from a larger number of qualified subcontractors, and this competition results in lower costs and better quality of work for the owner.

Like the payment bond, the bid and performance bonds also have a cost-reducing effect, because the majority of contractors, including subcontractors and material men, must liquify by bank loans needed assets which are tied up by "retainage," "short" estimates, and "security" deposits. However, because of the hazards inherent in the construction industry, its average members have never been considered as preferred risks in banking circles. This conservatism exists because despite the hazards of the construction business, the profits are generally much less than is popularly supposed, and because hard-earned, slowly accumulated working capital, if once destroyed by the unexpected, is extremely difficult to recreate in these times of crushing taxes on profits.

The use of bid and performance bonds defrosts a contractor's otherwise frozen working capital by reducing to a minimum the need for such collateral security to the owner, and removes an unnecessary limit on the capacity of contractors by permitting them access to the cash with which to meet payrolls and purchase materials on the favorable terms which contribute to lower costs and reduced bid prices.

Moreover, the services of contract bond agents have a cost-reducing effect. Agents have saved owners literally millions of dollars by interesting responsible contractors in jobs on which they had no intention of bidding, and in many cases, of which they had never even heard.

Another important, although unheralded by-product of suretyship, is the **loss prevention** activities of surety companies. Like fire and casualty insurance, which not only pay for losses to the owner but in addition provide services which prevent such losses, so also contract bonds have a preventive as well as a curative effect. Surety companies realize as keenly as anyone that contract defaults under certain conditions are hardly compensable and that the public interest is better served by faithful performance than by indemnification for loss. Moreover, from their own bitter experience the companies have learned that it pays to run toward trouble, instead of waiting to be overtaken by it, for they minimize their losses by taking prompt action. At one time there was more concern with the legal situation of a pending default than with improving the construction techniques. Fortunately, this situation has been reversed, and it is now common to engage highly specialized engineers when a contractor meets with

(*Continued on page 246*)

Marion 11-cu yd diesel electric shovel loading a Euclid 600-hp, 50-ton end-dump truck. A shovel of this capacity can excavate 40,000 tons daily.

H. H. EVERIST, JR.

Treasurer, Western Contracting Corp.

Sioux City, Iowa

Modern excavation methods and equipment

Among mankind's noblest and most pervasive compulsions is the urge to build. Our knowledge of the tremendous accomplishment of the Great Wall of China and the Egyptian pyramids, constructed entirely by human hand and brain more than 5,000 years past, is an awe-inspiring reminder of identical basic problems encountered in the modern world.

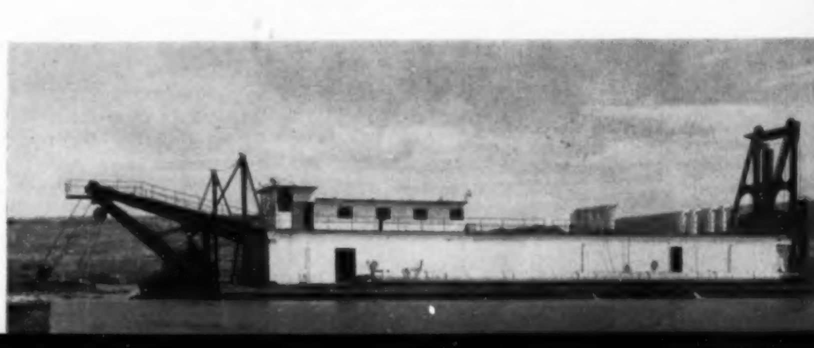
Essentially, with all our technological progress, we find that excavation and removal of material from the site of construction is an adaptation only of techniques and principles recognized and developed centuries ago. We have merely substituted other energies for man's—yet such energy and such performance that we may be rightfully prideful of today's earth-moving giants.

From the earliest times, tools and techniques were sought and developed to replace manpower, the most costly, least productive element in the construction picture. This is imperative today in view of mounting taxes, and the height to which wages have risen, and automatically has brought about the demand for the continuous development of machines of tremendous capacity and gratifying dependability.

Continuously increasing mechanical capacity is the principal reason for the tremendous number, variety, and extent of world-wide construction projects undertaken during the past fifty years. The annual total of more than a billion tons of excavation in the United States alone is eloquent testimony to a tremendously increased production level and is indicative of the degree of efficiency to which the machine has been developed.

To more fully illustrate this, we might examine a typical federal project now being executed in South Dakota, 162 river miles above Sioux City, Iowa—the Fort Randall Dam. As the first major dam upstream from the mouth of the Missouri River, it is of paramount importance in flood control, hydroelectric power, navigation, and irrigation for a vast area.

Owing to the breadth of the river at the construction site, and lack of a



World's most powerful portable 30-in. diesel electric hydraulic dredge used in the excavation of 5 million cu yd of sand and rock on the Fort Randall Dam project.

suitable foundation, a compacted earth-fill structure seemed most feasible. The embankment, nearly 2 miles long, $^1/_3$ mile wide at the base, and 160 ft high, requires 28 million cu yd of earth fill. An additional 32 million cu yd of chalk rock and overburden will be excavated for construction of the spillway and blanket protection of the embankment. To date, 25 million cu yd of rock and unclassified material have been moved by the open-cut load and haul method, and 5 million by hydraulic dredging.

It was found practicable to employ nearly all types of commonly used excavating equipment, and with discerning selection for a particular operation, plus proper maintenance, these tools are rendering excellent service. Equipment consists of shovels, draglines, scrapers, elevators, tractors, dozers, rock saws, drills, end- and bottom-dump hauling units, and a miscellany including motor graders, light plants, rubber-tired and sheepsfoot rollers, and manipulators.

Because of the presence of a considerable quantity of chalk rock and imbedded boulders in the unclassified material, shovels were selected as the principal excavating tool. Three electric shovels of $7^1/_2$-cu yd capacity were used initially and have subsequently been replaced by two 11-cu yd electric shovels. These are the world's largest machines on two crawlers.

Generally speaking, the greater the output of the machine, the lower is the cost per cubic yard of excavation. That progress is constantly being made in this direction is evident in average unit bid prices for excavation which have decreased 100 percent in the past twenty-five years. Thanks to the tremendous capacity of modern equipment and continuous improvement by designers and manufacturers, labor costs on an average excavation project are currently less than 25 percent of the total cost of construction, as compared to 75 percent only twenty-five years ago, in spite of a quadrupled wage scale.

Diesel Electric Shovel

Advanced features of an 11-cu yd diesel electric shovel, for example, that might be brought to attention, include portability due to sectionalization, enabling a 425-ton machine to be disassembled into ten completely integrated subsections. A reasonable reassembly schedule requires approximately 400 man-hours and two 50-ton cranes. Such a shovel, weighing 850,000 lb, will travel at a speed of 1.5 mph and complete three rotations per minute. These speeds equal or surpass the average cycle of far smaller machines. To the excavation contractor, this speed factor is of paramount importance. Mobility and speed accompanied by great size are prime factors in developing low unit costs.

Since an 11-cu yd shovel operating on an earth-filled dam will excavate 40,000 tons of earth daily, an extremely rugged, heavy machine is essential. High-alloy steel used in the upper and lower center sections, boom, dipper, and sticks contributes additional strength without increased weight. Principal sections are massive weldments composed of plates up to 3 in. thick, completely stress relieved.

The unit is powered by three two-cycle diesel engines developing a total of 1,700 hp. This power plant has proven economical of fuel, maintenance is low, and the ability of a diesel electric to work independently of any other power source is of considerable advantage. As most project areas are usually undeveloped, only rarely does the excavation contractor using a machine demanding 1,300 kw at peak load, find sufficient power available at the site.

Electric Power Performs Well

Electric power provides unsurpassed speed and smoothness of operation, resembling steam in its cushioning effect on shock loads and thereby reducing resultant destructive stresses. This soft power is conducive to development of a high availability factor. Full Ward-Leonard (variable-voltage) direct-current field control, with separately excited shunt-wound motors for each operation of the digging cycle—hoist, crowd, and swing—eliminates use of brakes and clutches. Heavy-duty direct-current hoist, swing, and crowd motors develop high torque at low speeds during the digging cycle and high speeds with low torque during free hoisting, swing, and retraction. Motors are fully reversible and, in the case of the hoist, two are used to drive a common pinion, thereby reducing the total inertia of the armatures of the twin motors to less than that of a single motor of equal rating. This lowered inertia facilitates quick stops and reversals of rotation. This is an important consideration in view of the 1800 reversals per hour required of the five motors controlling cyclic movements.

The diesel engines are direct connected to generators with a flywheel incorporated in the assembly to absorb regenerated energy developed when braking a motion during the cycle. The flywheel stores regenerated energy in the form of increased revolutions per minute while preventing momentary excessive overspeeding of the diesel engine. This stored energy is consumed during the succeeding cycle with consequent conservation of power. It is interesting to note that the 44,000 lb-ft^2 inertia of the hoist flywheel created a gyroscopic problem during the swinging motion.

To economically utilize tremendous shovel yardage, correspondingly sizable hauling units are obligatory. On the Fort Randall project, twenty 50-ton 600-hp end-dump trucks were employed, incorporating torque conversion and automatic transmission. With matched equipment, a shovel will average a 20-sec cycle or a 50-ton truck load per minute throughout the shift. To facilitate haulage, wide, uniformly graded, well-drained roads are provided from cut to fill area.

Portable Diesel Electric Dredge

To complete the contract on the Fort Randall Dam project, it was necessary to excavate under water some 5 million cu yd of blasted rock, boulders, and alluvial sand, and for this purpose the world's most powerful diesel electric hydraulic dredge was designed and built in 1951. This 30-in. dredge is the first of its size to be totally portable, a feature necessitated by the inland location of the project. Its 1,500 gross tons sectionalized require 57 railroad cars for shipment and nearly the same number for the attendant plant. This unusual size was determined by the nature of the contract, which required the pumping of 1 million cu yd of sand blanket in the base of the embankment within a 30-day period immediately following the closure and diversion of the Missouri.

Power is derived from nine two-cycle diesel engines developing 10,950 hp, of which 6,000 hp are available to the pump, 1,500 to the cutterhead, 2,000 for reserve standby, and the remainder to auxiliary equipment including service pumps, compressors, and lights. This power plant is capable of transporting blasted chalk rock one mile through a 30-in. pipeline at more than 1,600 cu yd per hour and can move sand at better than 3,000 cu yd per hour. This dredge introduced an entirely new technique in river closure during dam construction—a new chapter in excavation history.

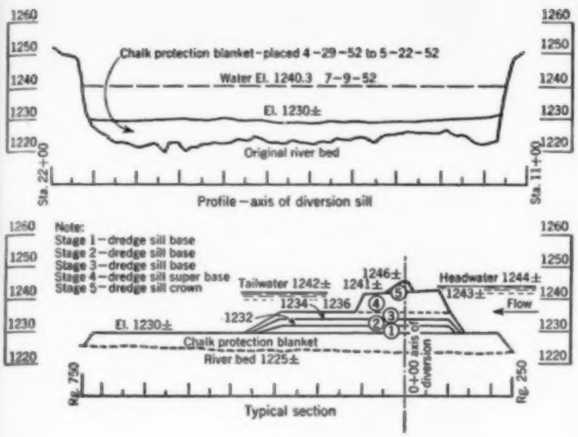


FIG. 1. Profile and cross section of diversion weir used in the closure of the Missouri River at Fort Randall Dam, South Dakota.

New Closure Technique Developed

This unique and highly successful procedure, developed by Dr. Lorenz G. Straub, M. ASCE, Director of the St. Anthony Falls Hydraulic Laboratory of the University of Minnesota, was accomplished in four stages (Fig. 1). Placement of all dredged material was effected by a spill barge operating at the end of one mile of 30-in. pipe passing continuously from bank to bank of the river.

The first step was stabilization of the river bank and the placement of a foundation of chalk rock as a bed protective cover in the river channel. The initial protective blanket, 3 to 6 ft thick, extended approximately 1,000 ft from bank to bank and an equal length parallel to flow. This operation also served a useful purpose in testing the ability of the dredge to place rock of adequate size and volume required for subsequent operations.

The second stage was construction of a base horizontally placed over this protective cover for a length of about 400 ft. This base was built in successive, 2-ft-thick, horizontal layers to a height just below the danger point of fouling the spill barge in the process of transversing the area during the subsequent operation of building the superbase.

The third step was construction of a superbase or the raising of a sill along the center line of the base by a progressive placement of dredge-fill layers from shore to shore of the river until the overflow depth had been decreased to 1 ft. Contrary to the method of base construction, on the superbase, building up of each strip was to its final height as the spill barge could not move over any part of the superbase once it was started. This superbase is designed to develop the greatest possible security during the most critical stages of construction. The flow over this structure, except for the extreme downstream section, was at all times subcritical and at continually decreasing velocity as construction progressed.

The superbase hedges against development of crevasses or erosion in somewhat the same manner as the base. It provides additional bulk volume in the embankment, which of itself is useful in case a crevasse should occur, but even more effective is its delaying of energy supercritical flows until a much later stage in operations and at much lower discharges over the embankment. A significant factor contributing to the success of this method is the considerable resistance to flow offered by the unusually wide crest of the fill area.

Interesting analytical studies and experiments were made to estimate speed at which a crevasse might develop once a break gets under way. Start of a break is often difficult to detect, as it normally proceeds quite slowly at first and then develops more rapidly, finally being retarded as it approaches equilibrium. In the event a crevasse does develop, the spill barge must concentrate on filling the break immediately before the rate of erosion exceeds the dredge capacity. It might be pointed out that the development of a crevasse just prior to complete closure would be the most troublesome and time consuming to repair. By use of a superbase, possibility of a crevasse is greatly reduced. In the event of such an occurrence, rate of erosion is materially retarded, allowing the dredge a better chance of closing the break before it reaches a critical stage.

The fourth stage of closure is placement of a sill crown by a final dredge operation, topping off the superbase, and completely cutting off flow over the underwater embankment. Total yardage involved in the entire protective closure operation was 900,000 cu yd.

It is obvious that close visual observation of the entire operation is essential and low points in the sill crest must be filled immediately from the spill barge. To facilitate detection of low points and possible scours, soundings were taken from the barge, and an electric graph recording depthometer, mounted in a motor boat, constantly checked elevation of the weir. Stadia readings from shore served to keep the boat in alignment. The discharge barge and floating pipeline were controlled by several variable speed winches to insure a level fill at all times.

Availability of large quantities of shot rock, up to 12 in. in size, together with a high-capacity dredge, made possible this closure technique on the Fort Randall Dam project.

The construction industry recognizes the invaluable contributions of innumerable items of equipment designed for specific applications. Among these is the diesel-powered tractor-drawn rubber-tired scraper which, possibly more than any other excavation tool, has revolutionized earth moving by the process of self loading, hauling, and finishing.

Contributions of Soil Mechanics

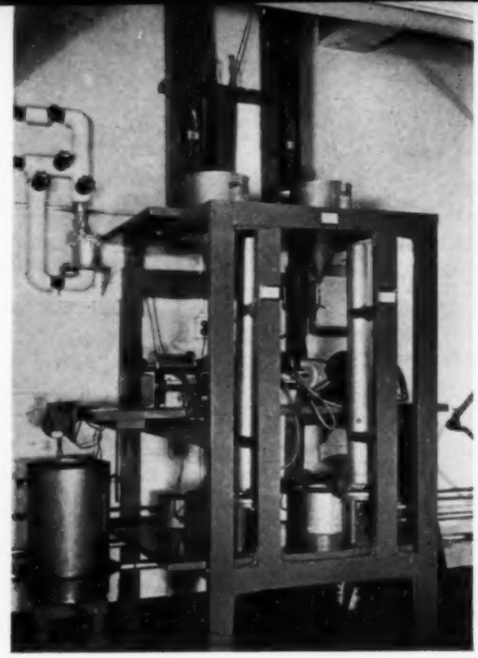
The subject of earth moving would be incomplete without mention of the new science of soil mechanics. The behavior of variable moisture content of large earth masses has been studied for some years, but only recently has test equipment and interest sufficiently developed to permit definitive analyses and conclusions. In the construction of earth-fill dams particularly, in foundation problems, and in road building, knowledge of particle size and other physical properties of earth is essential to safe and permanent construction.

In our era, we have seen the contours of the earth's surface altered at will—undreamed tonnages of earth lie just ahead and projects vaster than any yet conceived await the inevitable course of progress.

(This article was prepared from the paper presented by Mr. Everist before the Construction Division session presided over by A. H. Ayres, chairman of the Division's Executive Committee, at the Centennial Convention in Chicago.)

JOHN B. WILBUR, M. ASCE

Head, Department of Civil and Sanitary Engineering
Massachusetts Institute of Technology, Cambridge, Mass.



Research continually contributes to engineering progress. Hydraulic engineers, benefiting from advances in related fields, are increasing their skills, with result that water, a basic natural resource, in future will be conserved in the true sense. Studies in M.I.T.'s Civil and Sanitary Engineering Department include flow over a spillway, with hydraulic jump (above, left). In sanitary engineering field, experimental high-rate trickling filters (above) aid in solving nutritional and toxicity problems in industrial waste treatment.

Civil engineering looks to the future

As civil engineers we may well take pride in our profession. We can look to the past with an immense degree of satisfaction, deeply conscious of our heritage—not only of the vast reservoirs of knowledge that have been bequeathed to us, but of the high ideals of public service that have guided our predecessors as, under their stewardship, civil engineering has become the foundation of modern civilization. It is only necessary to consider the modern city—its dependence on highways, railways, airports, water supply systems, sewage disposal systems, hydroelectric power, skyscrapers, and other construction involving structural design—to realize that this statement is not overdrawn. Without these things, cities as we know them could not exist.

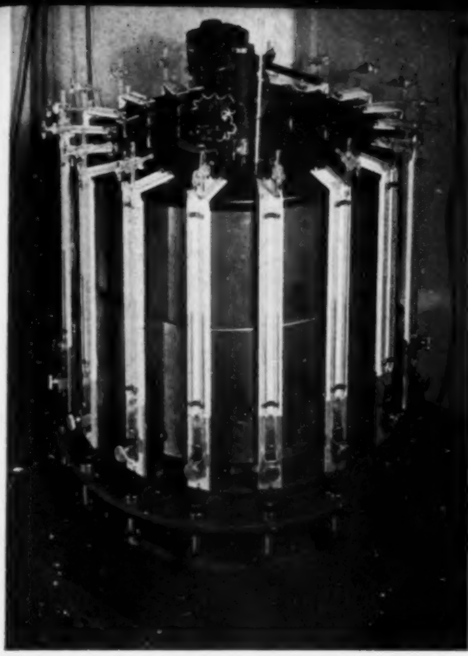
Yet our homage to the past does not imply that civil engineering today is in a staid or quiescent state; quite the contrary, it is in the midst of a fundamental evolution. This is a period of transition when empiricism is being set aside for rationalism, when civil engineering is rapidly emerging as a dynamic branch of applied science, heavily dependent on basic science itself and on a wide range of research programs, many of which are now under way.

What Lies Ahead?

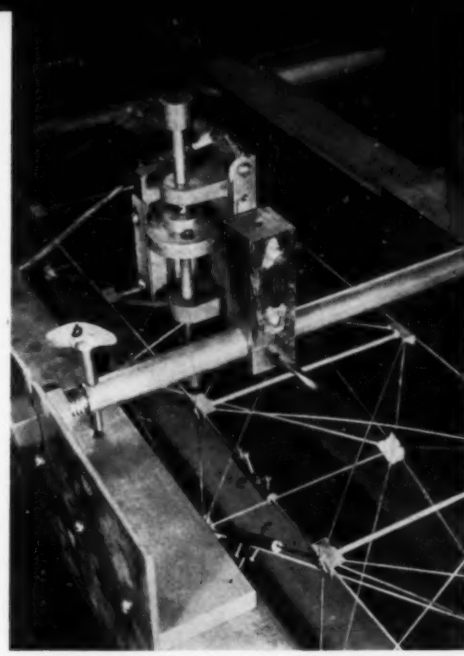
Within recent years this change has been very evident. There has been, for example, the effect of the science of soil mechanics on the more empirical art of foundation engineering, and the impact of fluid mechanics on hydraulic engineering. Still another instance is the recognition of the degree to which progress in sanitary engineering depends on an understanding of basic chemical and biological processes. The manner in which the present era will be evaluated by the civil engineer of tomorrow is to some degree a matter of speculation. However, it seems likely that he will view it as a period most typified by this transition from empiricism to rationalism, a time when the profession made rapid strides under the impact of basic science and research.

If it is difficult to anticipate tomorrow's evaluation of today's activities, it is even more hazardous to attempt to look into the future of the profession and speculate as to what lies ahead in civil engineering. But the uncertainties involved are scarcely sufficient to discourage the attempt. Since there are few projects of a civil engineering nature that do not require an estimate of future conditions, the realization that coming events may prove some expectations incorrect does not excuse the engineer from looking ahead as best he can. Actually, the hazard involved is related more closely to the details of such speculation than to the basic trends.

In looking to the future of transportation engineering, for example, there is ample room for uncertainty as to whether we should be thinking in terms of interplanetary transportation or of such mundane things as rocket ships and conveyer belts. From this auspicious beginning, the conservatism of the civil engineer comes to the fore. He decides that



Reclamation of by-products from industrial wastes often leads to returns that exceed cost of treatment. The Warburg Respirometer (above) is a valuable device for determining strength and treatability of various types of industrial wastes.



Model tests, such as this brass-wire test of a two-hinged spandrel trussed arch, help structural engineering keep pace with demands of construction.

it is safer and perhaps more meaningful if speculation is confined to things whose future pattern has at least begun to emerge.

To illustrate, it appears likely that the spheres of operation for the different modes of transportation will become defined more clearly. Thus the long haul of heavy solids, with the accent on speed, will undoubtedly be dominated by railroads on land and by ships at sea, whereas the long haul of fluids, especially on land, will be accomplished by pipelines. For the long haul of passengers and of lighter goods, air transportation promises to take the lead, whether over land or sea. For shorter hauls, however, whether of heavy goods, light goods, or passengers, the motor vehicle will probably predominate, with two important exceptions—namely, the transportation of passengers by rapid-transit systems in congested areas and the haul of heavy solids by conveyor belts along lines of exceptionally heavy traffic.

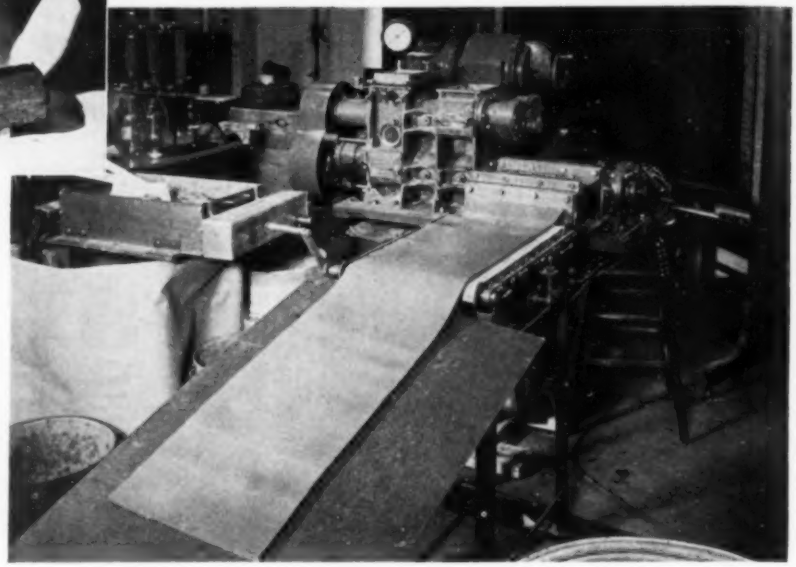
This clarification of function, together with new technological developments, will lead to transportation that is faster, safer, more comfortable, and, most important of all, less expensive. Such transportation will contribute effectively to raising the standard of living, not only because it will reduce the cost of distributing goods, but because better transportation, together with better systems of communication, will make it practicable to coordinate business and industrial activities at locations that are some distance from each other. Thus momentum will be added to the current trend toward decentralization of our cities, with the result that more people can live, work, and play in areas that are less congested. Behind all this, the civil engineer will play the important role of providing the basic ground facilities for all types of transportation, a service so vital that it touches every sphere of human endeavor.

More Food Will Be Needed

Similarly, in considering the future of hydraulic engineering, it is easy to let the imagination run rampant and envisage startling innovations. However, this is scarcely necessary in bringing into focus tomorrow's crucial role for this branch of the profession. We need only to remember that, with a growing population, it will become more and more necessary to grow food under diverse conditions of climate, and that water is the key to this problem. Hydraulic engineers, benefiting greatly by advances in aeronautics, oceanography, and meteorology, will so increase their skills that water, one of our most basic natural resources, will be conserved in the true sense; that is, it will be used more wisely in serving the needs of mankind. This will be done in such a manner that topsoil, that thin upper crust of earth on which the food supply of the earth also depends, will be conserved and used, rather than swept into the sea by erosion and floods.

More extensive development of water power, and perhaps the growth of wind power, will also be important in connection with the conservation of natural resources, especially in the conservation of nonrenewable fuels. It appears probable that nuclear power, although it will be available in some locations as a by-product of other operations, is not destined to compete in an important way with power from conventional sources. Its greatest use will be for special applications, often of a military character, where cost is a secondary consideration.

Major advances in sanitary engineering, achieved as a result of basic research in biology and chemistry, will create new methods of treatment that are both more rapid and more economical than those in use today. Speed of treatment will be especially important, since this will lead to much smaller treatment plants which, being less expensive to build, will become economically available to almost every city and



Treatment of soils with chemical agents which change the physical properties of the soils is a development that could have far-reaching consequences. Studies now under way in Civil and Sanitary Engineering Department of M.I.T. show possible method of placing calcium acrylate treated soils. Material passes through vacuum chamber for air removal, then through die onto subgrade of roadway. Subsequent polymerization of calcium acrylate causes solidification. Insert shows flexibility of treated material.

town for both water and sewage. Such treatment methods will be equally important in the field of industrial wastes, since plants will be more willing to attack this problem voluntarily, and it will become less necessary to resort to legislative pressure.

In this connection, the reclamation of by-products from industrial wastes, often leading to returns that exceed the cost of treating the wastes, will be a noteworthy factor. The sanitary engineer will without doubt become a key figure in the battle to conserve natural resources—not only by helping to use water more effectively and reclaiming for re-use part of the content of refuse, sewage, and industrial wastes, but by cleaning up lakes and streams, thus leading to larger crops from fish and wildlife, as well as to greatly improved recreational facilities.

Cheaper Structures Foreseen

Structural and foundation engineering will keep pace with the demands of construction, both within and beyond the scope of the civil engineering field. Better methods of analysis and design, ingenious new structural layouts, better use of existing materials, and the almost complete mechanization of prefabrication and erection, all will play their part in reducing construction costs. Decreased cost, of course, is of utmost importance, since more structures can be built with available funds. But perhaps the most spectacular advances in structural engineering will result from the introduction of new, and often synthesized, construction materials, once again demonstrating the vital role of basic research in civil engineering progress. The treatment of soils with chemical agents so as to change their physical properties is an example of a development that could, conceivably, have far-reaching consequences.

Perhaps, in the future, it will not be necessary to adapt structural design to soil conditions as they exist at a given site. It may be that the soil properties needed for a desired type of construction can be obtained by proper methods of chemical treatment, a more positive approach to the science and art of foundation engineering. However, the addition of chemicals is not necessarily limited to soil as a construction material. Possibly the properties of concrete can be modified in an exciting manner—changed, for example, so that much higher tensile stresses and strains can be withstood.

As the writer looks to the future, he would like to think that the fear of atomic warfare will no longer be a major consideration. Although other factors will be of utmost importance if this happy condition is to be brought about, the contribution of the civil engineer is not to be minimized. Hydraulic engineers will do much to increase the power and food supply of the world. Sanitary engineers will play an important part in improving the environment in which people live. Transportation engineers will help to distribute the goods of the world. At the same time, structural and foundation engineers, as the servants of the other three, will do their share by building the structures that make progress possible. All these activities will contribute directly to a higher standard of living throughout the world, and thus help to remove one of the major causes of war.

Social Considerations Increasingly Vital

There are certain common denominators in the foregoing speculations that deserve special mention, and the first of these is the increasing degree to which social considerations will underlie the planning of civil engineering projects in the future. The conservation of our natural resources, the protection of our people against man-made perils as well as the perils of nature, the betterment of the environment in which they live—these are examples of social objectives toward which civil engineers will direct increasing attention. This does not mean that we do not now have engineers who are socially minded, but rather that, in future, civil engineers will have to think more and more in terms of the broad social implications of the projects they build. Inevitably they will have to balance intangible as well as tangible factors in attempting to arrive at solutions that are best "on the whole." Also, they will need to recognize that the rigorous procedure of analysis, important as it is, has its limitations and must sometimes be supplemented with the less

formal and partly intuitive procedure of synthesis.

A second common denominator lies in the increasing importance of the basic sciences and of fundamental research. The current transition from empiricism to rationalism promises not only to continue, but to be emphasized. The importance of this trend, measured in terms of enabling the civil engineer to render more effective service, has already been strongly suggested. However, there are further implications of tremendous importance to the future of civil engineering, since a profession flourishes in a creative environment.

One of the first realizations that comes to the civil engineer who seeks better ways of doing things in his profession is that the other fields of science and engineering have much to offer in the way of new ideas and new tools. For example, aerodynamics has stimulated hydraulics, colloidal chemistry is helping soil mechanics, and the development of electronics is an aid to instrumentation in civil engineering research. Unless an engineer is involved in creative endeavor, he tends to follow the beaten path and this—in spite of the fact that his grave responsibilities are such that he cannot "make haste rapidly"—prevents him from profiting to the full by advancements in other areas.

The world of science is moving at a rapid pace. Herein lies not only the opportunity but the obligation of the civil engineer. We do not know just what advances will be made in the future, but we do know that advances will come. We know, too, that if we are well grounded in fundamentals we are far more likely to recognize the potential value of each advance to civil engineering, and to profit thereby.

Moreover, the birth of each new branch or phase of engineering will create new opportunities for the civil engineer. In the past, for example, aeronautical engineering made the airport necessary. Mechanical engineering, through the motor vehicle, led to the development of traffic specialties. Chemical engineering has created many of our stream-pollution problems.

Again, we do not know just what new branches of engineering will create new opportunities for civil engineers in the future. At the moment we might cite nuclear engineering with its attendant problems of structural design and waste disposal, but this is just an example that points the way toward things to come. Whatever the new developments may be, they are potentially fraught with opportunities for the civil engineer, but he must be armed with a fundamental approach to his profession if he, rather than others, is to gain the satisfaction that comes from entering new fields of service.

Teamwork Among Specialties

But if we are interested in the new areas of service that are created by other professions, we are even more interested in contributing as a full partner to some of the great advances of science and engineering that the future holds in store. As we examine some of the outstanding achievements of science and engineering during recent years, we cannot help but be impressed, and again the spectacular development of nuclear energy might be cited as an example, by the fact that teamwork between the various specialties not only in science and engineering, but in industry as well, has been the dominant characteristic. A wide, frontal attack has been involved, in which the rather artificial barriers of strict professional lines have been minimized, or even dissolved. Through coordination of activities, each group has contributed its best toward the solution of a problem that was too complex for any one group to handle by itself.

It should be observed, however, that if groups are to work together effectively, there must be a common ground on which all can meet. Empirical procedures, necessary as they may be in some instances, do not constitute an ideal base for collaboration. The reduction of procedures to basic elements—to basic science, which serves as a common denominator for all the fields of scientific and engineering endeavor—is far more likely to permit the kind of collaboration that promises to typify the future. This is true regardless of what field of engineering may be under consideration.

Thus research, while helping the civil engineer in his constant effort to serve mankind in his own professional area, serves an even greater purpose than this. It reduces his work to the common denominator of basic science and enables him to work more effectively as a teammate with his fellow engineers and scientists.

Earlier in this article it was suggested that tomorrow's civil engineer would view the present era as a period of transition from empiricism to rationalism, a time when the profession made rapid strides under the impact of basic science and research. Now it is further suggested that, as we attempt to appraise the future of civil engineering, the most important possible observation is that the trend now under way will flower. Tomorrow's civil engineer, imbued with an appreciation of research and well grounded in the basic sciences, will operate in a larger sphere that brings him into continued and intimate contact with the other branches of science and engineering, and will thereby open even wider the doors of opportunity for service to mankind.

It is true, of course, that not all civil engineers of the future will be direct participants in creative work. Those who put into practice the new methods that will be developed will always play a most essential role. But it will be those who find better ways of doing things who will blaze the path into the future, and it is on them that we should center our attention. It seems quite likely that future effort in the professional education of civil engineers will be especially focused on these potential leaders. Such a conclusion does not exclude from great importance the sound training of many men for the competent execution of vital tasks that must be carried out with utmost care and skill, but simply recognizes the special contribution to the profession and to society that will come from those who have been endowed with the spark of creative ability.

Three Keys to the Future

Transportation, water control, and suitable environment, for all of which the civil engineer provides structures and basic ground facilities, underlie every theater of human activity. Essential today, they will be needed even more vitally as civilization becomes more complex. The keys to the future of civil engineering are threefold:

1. A growing awareness of social values, leading to sounder planning.

2. An increasing emphasis on fundamental research, leading to better design.

3. The wiser management of men and equipment, leading to better methods of construction.

Of these three keys, research is the most important, for only by extending the boundaries of knowledge can a profession maintain its stature, and forge its way to the new frontiers that always lie ahead.

(*The accompanying photographs show research work under way in the laboratories of M.I.T.*)

S. C. HOLLISTER, M. ASCE

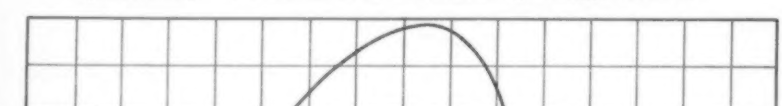
Dean, College of Engineering, Cornell University, Ithaca, N.Y.

Engineers must be upgraded to solve manpower shortage

It has been our common habit of thinking that America has an inexhaustible supply of competent manpower. If we are short in a given category we think all that is necessary is to train a few additional people and the shortage will be overcome. Where the people will come from, and who should receive the training, have never been matters of serious concern. The present shortage of engineers has given rise to studies of the potential manpower in our total population for supplying the needs of specialized personnel. By making an estimate of this potential as it relates to the supply of engineers, it becomes possible to predict what the future may hold for the profession in this direction.

There are many qualities essential to the making of an engineer. He must be a person of high integrity, greatly interested in his professional work, dedicated to the protection of the public welfare, interested in building and operating machines and installations, and having the necessary courage and persistence to finish the job in hand in spite of obstacles. And underlying all this, he must have the high level of intelligence to acquire the technical knowledge and the understanding of scientific principles on which his work is based. He must possess the power of analysis and at the same time be able to synthesize his knowledge and coordinate the various principles involved in solving the problem at hand. It is clear then that although his character and personality are important adjuncts, he cannot succeed without a high level of intelligence. This does not mean that if he has the proper level of intelligence and does not have the other characteristics he can become a successful engineer. It simply means that the first essential requisite to his success is the required level of intelligence.

FIG. 1. Adjusted distribution of scores made on Army Classification Test in World War II shows percentages of trainees in various intelligence ratings. From *Journal of Educational Psychology,* Nov. 1947.



Pertinent Statistics Investigated

Several noteworthy studies have been made over the past forty years which indicate the placement of engineers on an intelligence scale that at the same time covers other groups in the population. Three leading studies will be mentioned. The first was that made of the educational system of the State of Pennsylvania by the Carnegie Foundation prior to the First World War. The second was the very large classification of men taken into the Army during the Second World War. The third, and the most recent, is the report of the Educational Testing Service in connection with the deferment program of college students for the Selective Service System. In all three of these studies, engineers were placed in the topmost intelligence group of the population. They are in the group

that must also furnish the country with scientists, physicians and other high-grade leaders and professional people.

In order to be more specific I have chosen the Army General Classification Score, which was used to classify about 9,300,000 men during the Second World War. This was by far the largest population group ever subjected to a single test, cutting across all strata of the male population. The distribution of the individual scores for this large group is shown in Fig. 1.

Study of the various data taken for this classification indicates that a score of 120 or better encompasses those who could successfully complete a course of engineering education. This does not mean that each individual will have a score of 120. Rather it is a statistical figure such that deviations above and below it average out.

The area under the curve above the score of 120 represents 17 percent of the total area under the curve. In other words, 17 percent of the male group examined made a score of 120 or better. With this information it is possible to estimate the potential of the group having the necessary intelligence to pursue engineering education and practice successfully.

Census figures indicate that the average number of males reaching the age of 18 during a calendar year is approximately 1,100,000. We may assume this figure to approximate closely the number of males reaching college age during a given calendar year. Certainly some boys reach college either older or younger than 18, but the deviation is similar year after year, and therefore 18 can be taken as the average for our purposes. Taking 17 percent of 1,100,000, we find that 187,000 males reach college entrance age in a given calendar year, who possess the required intelligence level successfully to pursue an engineering course. This same group, however, must provide doctors and others in the top level of the healing arts; mathematicians, physicists, chemists and other scientists; high-level professional and business people; and the upper portion of the skilled crafts.

Another measure of the validity of 120 as the bottom score for engineering is given by the fact that this score includes the top 10 percent of policemen, fire-fighters, locomotive firemen, railway brakemen, crane and shovel operators, truck drivers, structural steel workers, electricians, plumbers, painters, general carpenters, bricklayers, welders, tailors, cooks, and similar skilled workmen. The category also includes 25 percent of machinists, toolmakers, instrumental musicians, aircraft and airplane engine mechanics, radio repairmen, postal clerks, and similar craftsmen. For these reasons the score of 120 is not thought to be too high to be taken as the bottom limit for engineers.

What proportion of the 187,000 males is available for allocation to engineering training? A handy index might be the proportionate numbers presently in various categories, these having been supplied from this intelligence group over an extended period of time. According to census figures, there are approximately 400,000 engineers, 200,000 doctors, and 200,000 scientists. If we estimate conservatively 400,000 other professional people and 400,000 top-level craftsmen, the total becomes 1,600,000, of which engineers form one fourth. The figures for other professional persons and high-level craftsmen in this computation are probably low and the engineers actually form less than one fourth, depending on the extent of the error in the estimate.

We can say that about 44,000 males from the group of 187,000 represent all that can be expected to flow toward engineering schools under normal circumstances, with the population at the present level. Census figures indicate that this rate will remain substantially constant until 1960, after which there will be a gradual increase, continuing at least until 1975.

In this group of 44,000 males who are potential engineering students, there are individuals who do not possess the emotional stability, determination, continuing interest or financial means to follow through a program of engineering education. As in the case of other college programs, there is a gradual falling off in the enrollment in successive years of the four-year course until only about half of the original number that entered the class are graduated. Thus the expectation under normal circumstances would be a graduating class of about 22,000 men a year.

Enrollments Substantiate Statistics

It is of some interest to compare these estimates with current enrollments. Last fall 38,000 freshmen were enrolled throughout the country in engineering courses. This coming fall, as a result of vigorous attempts during the past year to stimulate the interest of high school students, it is expected that there will be a substantial increase, possibly to 48,000 or 50,000. These enrollments would normally produce graduating classes of from 19,000 to 25,000. It will be interesting to note this coming fall the extent to which increased enrollments in engineering schools will reduce enrollments in other professional fields. I suspect we are at the point where increasing enrollment in one professional field is in fact a case of robbing Peter to pay Paul.

In this study women have been excluded because there are not enough women engineers at present to justify the rigid statistical analysis here applied. Actually the number of women now practicing engineering would not change the figures here given appreciably.

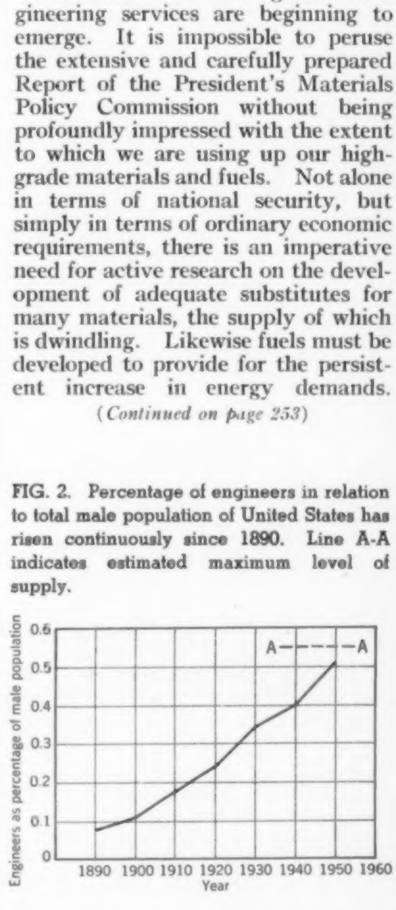
Profession Faces Readjustment

All indications point to the fact that there will be a profound change in the engineering profession in the next quarter century. This will come about largely because the need for engineers will rise at a more rapid rate than the supply. Technological processes in almost all fields are becoming more complex. This fact alone calls for a larger annual output of engineers.

Other factors that will profoundly increase the need for high-level engineering services are beginning to emerge. It is impossible to peruse the extensive and carefully prepared Report of the President's Materials Policy Commission without being profoundly impressed with the extent to which we are using up our high-grade materials and fuels. Not alone in terms of national security, but simply in terms of ordinary economic requirements, there is an imperative need for active research on the development of adequate substitutes for many materials, the supply of which is dwindling. Likewise fuels must be developed to provide for the persistent increase in energy demands.

(*Continued on page 253*)

FIG. 2. Percentage of engineers in relation to total male population of United States has risen continuously since 1890. Line A-A indicates estimated maximum level of supply.



American highways

—how to measure

It is evident that American roads are critically inadequate. But there is considerable confusion about the situation with the result that remedial action is developing slowly. There is obviously a need for a method of evaluating our highways so as clearly to portray their inadequacies and encourage improvement programs that will be understood and supported by the public.

Do We Need More Mileage?

It has been stated that, if all the motor vehicles built since the end of World War II were lined up end to end on all the highways built in the same period, there wouldn't be enough highways to accommodate the vehicles. This kind of word picture is dramatic, but unfortunately its implications are inaccurate. It isn't more miles of highways that we need. Actually, we have plenty of miles of highway—more than are needed in some places.

The Colorado Highway Planning Committee, in its report of October 1950, indicated that over 29,000 miles of roads out of the total state mileage of 80,000 could be abandoned as public facilities. This conclusion was based on county by county evaluation by local people. No doubt Colorado represents an extreme case, in part because of the consolidation of smaller ranches into larger holdings and in part because of abandonment of various mining activities. However, other states have reported a considerable mileage of roads that are no longer needed or that provide nonessential alternative routes. Connecticut, for example, in 1946, after providing for the abandonment of a considerable mileage of public roads no longer in use, reported that less than one-half of the remaining mileage of unimproved rural roads provided an essential service even excluding those leading to a single farm or dwelling. So it appears that there is more need for contraction than expansion of the total road network, and that American highways are largely adequate as regards mileage.

The annual improvement programs of the state highway departments illustrate the relatively small requirements for expansion of the network. According to the U. S. Bureau of Public Roads Report for 1950, the state highway departments built

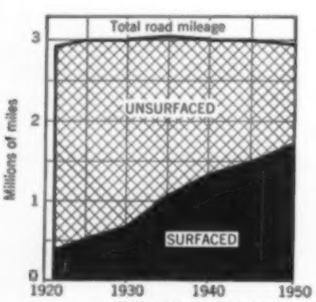


FIG. 1. Mileage of rural roads in the United States has remained practically constant since 1920, but surfaced mileage has steadily increased.

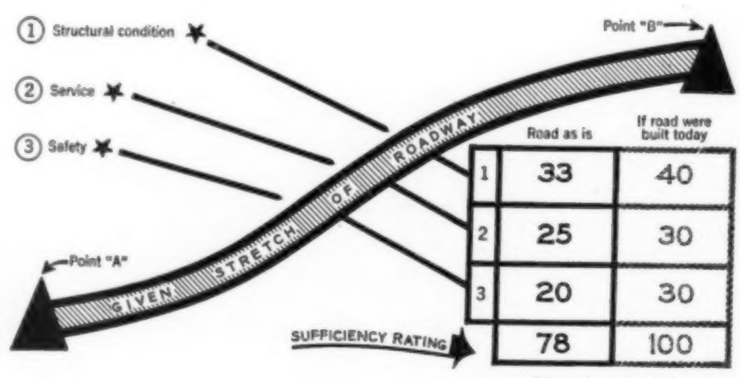


FIG. 2. "Sufficiency rating" is composed of three factors. A total rating of 100 indicates a road completely adequate for the traffic served.

their adequacy

ROY E. JORGENSEN, M. ASCE

Engineering Counsel,

National Highway Users Conference

Washington, D.C.

44,265 miles of roads during the year. Of this total only 1,838 miles, or 4 percent, represented an addition to the existing mileage; and this addition was almost entirely due to construction on new locations where the old road still had to be maintained for local service. In other words, the additional mileage of highway was made necessary to modernize existing facilities and not to expand the network.

We Are Largely "Out of the Mud"

The good-roads movement of thirty or more years ago was aimed at getting the motorist "out of the mud." The development of highway transportation at that time was being retarded by the lack of stable road surfaces. Even the main intercity routes were not of all-weather construction. Now the major highways provide dependable year-round service and, in a number of states, almost all places of business, farms, and other residences are served directly by surfaced roads. In other states, most roads on which improvements to all-weather surfaces are economically justified have already been improved. The Board of County Engineer Consultants to the U.S. Bureau of Public Roads stated, under date of March 22, 1950: "The total improvement of all essential roads to an all-weather level would be economically unsound."

The trend over the past thirty years indicates the tremendous strides that have been made in expanding the mileage of surfaced roads. The total rural road mileage has remained almost constant—roughly 3 million miles. But the surfaced mileage has increased as follows:

1921	387,000 miles
1930	694,000 miles
1940	1,340,000 miles
1950	1,679,000 miles

These data are shown graphically in Fig. 1. There still is work to be done in extending the pattern of all-weather roads "beyond the second cross-road," but lack of those improvements is not a major problem in most of the country today.

Problem Is Not Simple

We don't then need a lot of new roads or surfacing of existing unimproved roads. Still we are faced with critical inadequacies and congestion that amount to a highway crisis. What is the matter? What do we need? There is no easy answer. The answer thirty years ago was simple—"get the motorist out of the mud"—but today the problem is more complex.

Some of today's highway problems are created by structural inadequacies—broken pavements and weak subgrades. Some difficulties can be charged to deficiencies in road alignment and width, which restrict the free movement of motor vehicles. In some cases, hazardous conditions are created by short sight lines, inadequate shoulders, or combinations of these factors.

SUFFICIENCY RATINGS FOR AN ACTUAL STRETCH OF HIGHWAY

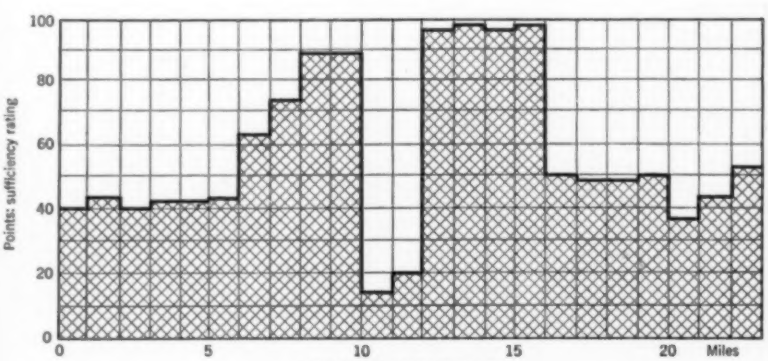


FIG. 3. Profile method permits graphical presentation of sufficiency ratings for actual stretch of highway, mile by mile.

Sufficiency Ratings Measure Adequacy

"Sufficiency ratings" offer a means of evaluating the adequacy of highway sections on a consistent and comprehensible basis. The evaluation takes into account three main factors: (1) the structural condition of the road, (2) its effectiveness in serving its traffic, and (3) the degree of hazard associated with its use. The point system of evaluation is

illustrated in Fig. 2. The procedure assures consistent application to all road sections. The higher the rating the better the road in its structural and operating characteristics. A rating of 100 represents a road completely adequate for the traffic it serves.

With sufficiency ratings established, it is possible to indicate the adequacy of the road system in various ways. A profile may be used to show graphically the sufficiency rating from section to section along a route. See Fig. 3 for an example. Maps may also be symbolized to portray the sufficiency rating for all sections of the road system. Listings provide another effective method of presentation, particularly when the road sections are listed in order of their sufficiency. Program progress can be effectively plotted, as shown in Fig. 4.

Following the lead of the state of Arizona, more than 20 states and the Bureau of Public Roads now utilize sufficiency ratings. The BPR is expected to have all the federal-aid primary highway systems rated for all the states by the end of 1952. A comprehensive nationwide appraisal of the adequacy of our most important highways will then be possible. Meanwhile, the work done in analyzing the problem in some states gives an indication of what our highway inadequacies are. While most of the sufficiency ratings so far have been applied to major rural highways, the approach, with proper modification of formulas and procedures, is equally suitable for urban highways and for secondary rural roads.

Arizona was the pioneer in developing the sufficiency rating of highways. This rating procedure was started there in 1946 by Karl Moskowitz, M. ASCE, while he was employed by the U. S. Bureau of Public Roads. The annual reports published by the Arizona Highway Department demonstrate the great value associated with the continuing inventory of the highway system provided by sufficiency ratings.

In the 1952 report for the federal-aid primary system in Arizona, the Highway Department reports 860 miles of the system's total of 2,462, or 35 percent, as rating less than 70. The Department recognizes a rating of less than 60 as indicating inadequate parts of the system and, since 1947, has been directing a program for the improvement of sections rating lower than this. Because Arizona maintains a continuing inventory with its sufficiency ratings, it is possible to evaluate the progress being made in eliminating critical deficiencies as well as to judge the current status of the system. In the 1952 report, progress since 1947 is reflected as follows:

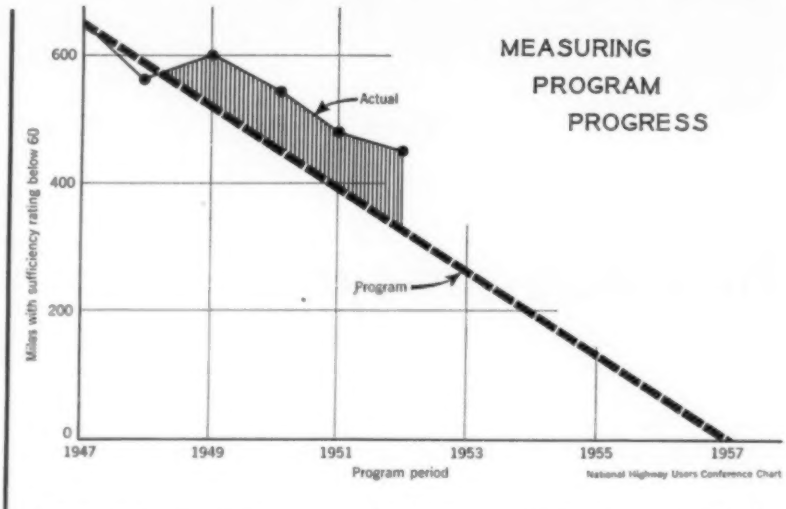


FIG. 4. Program progress is measured by plotting it according to program period.

Year	Miles at or Below Sufficiency Rating of 60
1947	650
1948	564
1949	601
1950	538
1951	479
1952	448

Colorado. The 1951 Highway Department report of sufficiency ratings for the federal-aid highway systems in Colorado, states that:

It is recommended that all sub-sections on the federal-aid primary and secondary systems with a net rating of less than 70 be given immediate consideration for improvement either by construction, reconstruction or extensive maintenance operations.

On the basis of this statement, the critical deficiencies can be summarized by taking the mileage with ratings of less than 70, as follows:

	Total System Mileage	Mileage Below 70	% of Total Mileage
All federal-aid systems	7,436	1,342	18
Interstate system	616	310	50
Federal-aid primary*	3,241	595	18
Federal-aid secondary	3,579	437	12

* Excluding interstate.

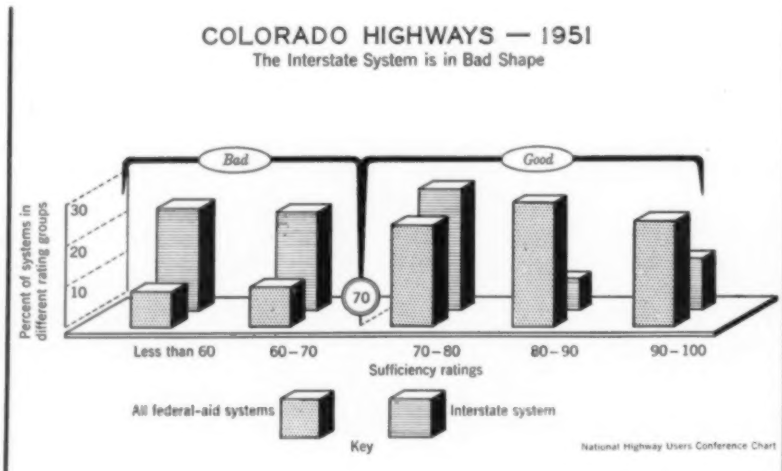


FIG. 5. In Colorado, interstate system is in bad shape (1951). Sufficiency ratings are used to measure extent of problem.

This points up a situation that exists in most states. A much greater proportion of the most important highways is critically deficient than is the case for the rest of the road system. While only 18 percent of all federal-aid systems is critically deficient, 50 percent of the interstate system is deficient. (See Fig. 5.) The interstate system was laid out to include a limited mileage which includes the routes most vital to the economy of the country in peace or war. Nationwide, the system covers less than 40,000 miles, only $1^1/_3$ percent of the total road mileage, but it carries 20 percent of all rural traffic and 10 percent of the urban traffic.

As reported for Colorado, the critical deficiencies do not represent a large percentage of the total mileage, but do represent the mileage on which a comparatively large percent of the total travel occurs. As this part of the road system is bad, so must its influence on highway transportation in Colorado be bad. In no other way can such striking improvement in the highway situation be accomplished as through modernization of the interstate system. In the interest of getting efficiency and safety on Colorado highways, it is imperative that steps be taken promptly to correct the critical deficiencies that exist on one-half of the most important highways in the state. This Colorado situation is typical of much of the country today.

Idaho. As of 1951 the State of Idaho published a highway sufficiency rating study covering its system of 4,511 miles. A rating of 65 represents the value above which road sections are tolerable and below which they are unsatisfactory. The report places 1,301 miles, or 29 percent of the system, as intolerable because of a rating of 64 or less. In addition, Idaho reports 63 miles which rate 65 or higher but have a critical rating in one of the three factors of "condition," "safety," or "service," and should be included for current program consideration. Thus 30 percent of the system is in immediate need of improvement.

Louisiana. The Highway Department of Louisiana published a sufficiency rating report for 1950 covering 2,284 miles of primary roads. See graphic presentation, Fig. 6. This is a small percentage of the total road system and represents the routes of greatest traffic importance. The report shows that 1,283 miles, or 56 percent, have sufficiency ratings below 70. Taking the more critical rating of 60, it is found that there are 749 miles below this rating—33 percent of the total.

Oklahoma. The Oklahoma Highway Department has made a sufficiency rating report on its federal-aid primary system as of 1951. The system totals 6,790 miles, excluding urban sections, projected routes, and jobs under construction, and 3,835 miles are reported as "adequate," with ratings from 80 to 100. This is 56 percent of the total mileage. There are 1,605 miles, or 24 percent, reported "tolerable," with ratings between 70 and 80. Twelve percent, or 820 miles, are shown as "inadequate," with ratings between 60 to 70; and 8 percent, or 530 miles, are reported as "critically inadequate," with ratings below 60. The combination of "inadequate" and "critically inadequate" represents 20 percent of the total system mileage. See graphical presentation, Fig. 7.

Virginia. In 1951, the Automotive Safety Foundation made a survey of 2,475 miles of the most important highways in Virginia in cooperation with the U.S. Bureau of Public Roads and the Virginia Highway Department. The sufficiency ratings show 817 miles, or 33 percent, rating less than 70. By an alternative evaluation, using "tolerable standards" against which to relate the various significant highway features, such as width, curvature, etc., it was determined that 841 miles are critically deficient. The close agreement between the "tolerable standards" evaluation and the deficiencies below sufficiency ratings of 70, indicates the reasonableness, in the Virginia study, of taking 70 for the division point between critically deficient and adequate highways.

Sufficiency ratings provide a qualitative measure of the degree of adequacy of a highway system. While it is not possible to state that any particular rating represents the dividing point between the adequate and the inadequate parts of a highway system, it is possible to set such a dividing or cutoff point based on evaluation of either hypothetical or actual road sections which are considered to represent the limiting condition of acceptability or adequacy. In Colorado a rating of 70 is

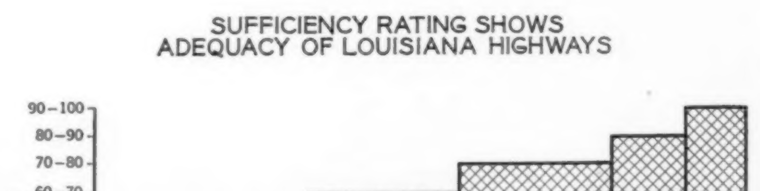


FIG. 6. Sufficiency ratings show adequacy of primary road system of Louisiana.

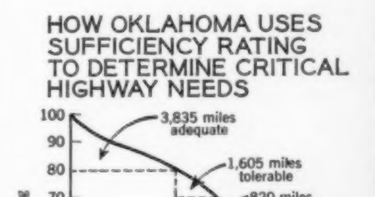


FIG. 7. Oklahoma uses sufficiency ratings to determine critical highway needs.

considered as the point below which road sections are inadequate. The Automotive Safety Foundation study in Virginia arrived at the same cutoff value. Oklahoma has set 70, but qualified it by further classification of sections below 60 as "critically inadequate." Idaho has established 65 as the lower limit for adequate road sections. Arizona and Louisiana have not indicated any conclusion on this point, but Arizona has been directing its program toward elimination of critical deficiencies below 60. It must be recognized that there will be differences in the cutoff values established for different states, primarily because the sufficiency rating formulas used are not identical.

In time it is hoped that some economic criteria will be developed for establishing the division point between adequate and inadequate facilities. Computing benefit-cost relationships for projects to correct deficient road sections of different sufficiency rating values would provide an approach that has promise, particularly in view of the considerable application of the benefit-cost relationship in highway planning in some states at the present time. This approach would be aimed at establishing a cutoff point below which benefits from improvements could be expected to provide highway transportation benefits in excess of the costs associated with the improvement.

In the absence of cutoff points established by economic evaluations, it will be necessary to continue to follow an empirical determination of what is adequate and what is inadequate but, even so, the sufficiency ratings provide a simple, readily understandable means of classifying highway adequacy. Furthermore, the extent of critical deficiencies falling in different sufficiency rating groups is readily determinable, and provides the basis for a continuing highway program aimed at getting adequate highways.

Our present critical highway problem has arisen largely because of a lack of a continuing inventory of highway needs so presented as to have significance to the highway users and the general public. The highway problem is critical because it has been confusing. Confusion has resulted in inequitable dispersion of existing highway-user tax revenues. It has encouraged unsound modifications of good highway finance proposals, and it has prevented a continuing effort to meet the most urgent highway needs and to raise the level of efficiency of the highway network.

What Is Current Adequacy?

The sufficiency data summarizations, as previously presented, point out the extent to which existing rural roads are deficient in certain states.

It may be surprising to some that our entire road system is not "washed up." However, the sufficiency ratings show that nationwide, it is likely that 70 to 80 percent of the federal-aid highways (roughly 650,000 of the major highways and principal feeders) are in good condition. Probably only 20 to 30 percent are in urgent need of improvement.

This does not mean, however, that the American motorist can expect to drive 7 to 8 good miles for every 10 he travels. The deficiencies are far more critical and extensive on the most important highways, the ones on which the motorist drives a large part of the time. Thus, if he makes a trip between two major cities, he is likely to find 50 percent or more of the mileage critically inadequate, rather than 20 to 30 percent, the average for all federal-aid routes. The situation will vary from state to state and from route to route within each state, but the pattern is fairly consistent. The routes most vital to free and safe traffic movement are the least adequate.

The urban situation is similar to that in rural areas but even more critical as far as major routes are concerned. Modern highways—parkways and expressways—are only now being started in many of our major cities and their suburbs. Elaborate systems of such facilities, and adequate parking terminals, provide the only hope for the relief of urban congestion. Even in cities where parkways and expressways have been completed, the development is so limited as to bring small relief. Whereas it may be expected that as much as 50 percent of an important rural route will be adequate, it is doubtful that as much as 10 percent of the urban connector will provide equivalent service.

In conclusion, four main points should be emphasized:

1. We do have a good road system as far as its extent is concerned.
2. We have got well out of the mud and are continuing rapidly the expansion of all-weather roads in rural areas.
3. We have critical inadequacies of relatively large parts of major routes, rural and urban. It is these inadequacies and their vital effect on our entire economy which has created today's highway crisis.
4. Great promise of attainment of adequate roads lies in increasing public awareness and understanding of the problem. When, as a result of engineering evaluations of highway inadequacies, the people understand what must be done, they will act to obtain adequate roads for a stronger America.

(This article is based on Mr. Jorgensen's paper presented before the joint session of the Construction and Highway Divisions presided over by DeWitt C. Greer, M. ASCE, at the Centennial Convention in Chicago.)

Sufficiency ratings provide a single numerical value, against a scale of 100, to reflect degree of adequacy of each section of highway system. For example, road at left gets low marks on condition, traffic service, and safety, whereas route at right would get sufficiency rating of 100.

REX M. WHITTON

Chief Engineer
Missouri State Highway Commission
Jefferson City, Mo.

A long look at highway maintenance

Highway maintenance has approached an acceptable efficiency only during the last quarter century. This has been accomplished largely through mechanization, by the training of highway maintenance personnel, and through the awakening of engineers to a realization that highway maintenance means far more than just mending or smoothing a rough or broken roadway.

Just what is highway maintenance? It is the preserving and keeping of each type of roadway, roadside structure, and facility as nearly as possible in its original condition as constructed or as subsequently improved. It means patching holes, filling ruts, cutting corrugations, pouring cracks, cleaning ditches and culverts, removing snow, spreading cinders, fighting floods, mowing weeds, erecting proper traffic controls and warning signs, and innumerable other operations which contribute to keeping a highway smooth, safe, efficient, and attractive. The end result of adequate highway maintenance is smooth and safe roadways, clear waterways, and clean rights-of-way.

In the history of road maintenance in the United States, the years prior to 1900 may be marked off as of little consequence; those between 1900 and the 1920's may be labeled as educative and preparatory; and the last quarter of the century may be cited as the period of awakening and actual progress. Up to the

Left: Mending roads as late as 1900 was by hand methods, with axe, pick, and shovel. Right: Split-log drag behind four-up team was one of earliest pieces of equipment devised to improve highway maintenance—before 1890.

early 1900's, with but few exceptions, maintenance was a local responsibility, generally charged either to townships or to counties. Usually the county was divided into local districts and virtually all authority delegated to untrained men appointed or elected to care for the roads. When and if any actual work was carried out, it was largely by persons working out the highway taxes levied by the individual communities.

Road Taxes "Worked Out"

During this "dark age" of our nation's roads, the town plow, the axe, the hoe, the pick, and the shovel were the principal tools for making repairs. A summary of the procedure actually followed in Massachusetts in 1866 is given in an 1888 history of transportation compiled by J. L. Ringwalt, early-day editor of *Railway World*. The following abstract provides us with a typical picture of maintenance as it existed until about 1890:

"Surveyors," elected at town meetings and having no particular skill, were charged with directing the work. Labor was performed by persons old and young, rich and poor, working out a highway tax. The "surveyors" were farmers who took turns at the job, often seeking it so that they could repair their own road.

Repairs seldom were made at the time most needed, but rather when it was convenient for brother farmers to work—after planting or harvesting was done. Citizens in town meeting would fix the prices to be paid for the labor of men and animals, the rate being set at the highest level commanded by the best men and teams, because each voter had a direct interest in that price.

Then came the actual day for repairing the road. Ringwalt describes it thus, in an 1866 *Agriculture Report:*

A motley assemblage gathers, of decrepit old men, each with a garden hoe; of pale, thin mechanics from their shoe shops, armed with worn-out shovels; half grown boys, sent by their mothers who, perhaps, are widows; with, perhaps, the doctor, the lawyer, and even the minister, all of whom understand that working on the road does not mean hard labor, even for the soft hands.

Farmers bring their steers . . . the old mare in the lead, with a cart. A new citizen drives up, with rickety cart and mortal remains of a railroad horse . . . . The only effective force consists of two or three yokes of oxen and a half dozen men hired by the surveyor with money paid by non-residents and men whose time is of too much value to waste on the roads.

Cattle are put to the big town plow . . . boys ride the beams, drivers put on the lash. Gutters, half filled with sand and soil and leaves of a half dozen seasons are ploughed up. . . . Teams then stand idle and this mixture, more fit for the compost heap, is thrown upon the road by the old men with their hoes and shovels. The occasion is regarded more as a frolic than as serious labor.

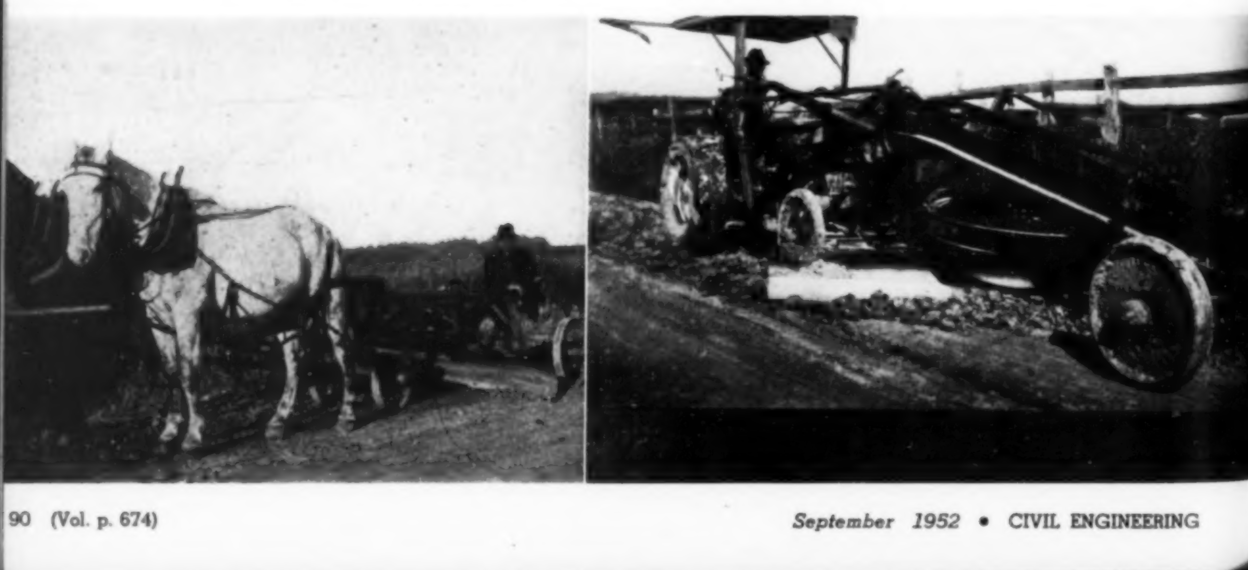
The report from which Ringwalt quoted, drew this conclusion on the procedure:

No one who has once witnessed the process of "mending the roads" in a small New England town needs any argument to convince him that a system more ingeniously devised to accomplish nothing was never invented.

Continuous Maintenance Needed

The period prior to 1900 did, however, bring some developments that were to have an important influence on modern methods. For example, Jerome Tresaguet, the great French road engineer of the late 1700's, not only advanced the idea of lighter pavements and crowned subgrades, but also stressed the necessity for continuous, organized maintenance, instead of intermittent repair, to keep roads in condition at all seasons of the year.

Tresaguet organized the "cantonnier" system of maintenance which, manned at first by untrained laborers, soon developed into a specialized maintenance organization paid for and supervised by the French Government. Also, he initiated the idea that rapidity of wear is in direct proportion to bad road condition. Therefore, to insure the longest possible life, it becomes mandatory to preserve the integrity of the surface



Left: Horse-drawn wheeled patrol grader was an early rig built for road maintenance. Right: This one-man self-propelled power grader, one of first used by Missouri Highway Department, shows that solid rubber tires were coming into use early in 1920's.

by prompt and incessant maintenance.

Thomas Teleford, a famous road builder of the 1800's, made an observation in 1820 that is just as important and true today as it was when spoken:

> It ought never be forgotten that in order to have the surface of a road perfect, it must be kept completely dry.

He also said:

> A certain number of laborers ought always to have the care of the surface of the road, and never quit it for a single day to do anything else; they will always have sufficient to do in spreading materials in ruts and hollows, in scraping the road, in cleaning out the side channels and keeping open the watercourses, and generally in maintaining the road in a clean and sound state. A few men constantly so employed will do a great deal toward preservation of the road.

In Missouri, the plank road craze came in about 1849. Nearly fifty companies were chartered to establish toll highways using plank as the surface layer. In other parts of the country, during an earlier period, corduroy roads were built consisting of logs laid side by side as the supporting element of the wagon load. These plank roads gave way to macadam within a few years because of the fast wearing and warping of the plank. In some places, warping of the plank was controlled by placing creek gravel on the plank ends. This resulted in the discovery that creek gravel made an excellent surfacing material, and its use on low-traffic roads has continued to this day.

Maintenance Equipment Mechanized

Numerous other developments in the later half of the nineteenth century contributed to present-day methods: duPont's new blasting powder in 1856; Blake's introduction of a jaw rock crusher in 1857, and a gyratory crusher in 1881; the birth of the petroleum industry in 1859, when the first oil well was sunk at Oil Creek, Pa.; discovery of the internal combustion principle in 1859, with the first vehicle propelled by an internal combustion engine being built early in the 1860's; and the importation of a steam roller in 1869, when the Commissioners of Central Park, New York City, purchased a 15-ton machine manufactured in England.

The bicycle, which was to plant an early seed of desire for better roads, appeared in sizable numbers in 1877. In that same year the steam mortar mixer was introduced. William H. Diedrick, of Fresno County, California, perfected an improved earth scraper that was to become the parent of the one so widely used for many years, before the wheeled scraper was invented in 1884. The first portland-cement concrete pavement in this country was laid in Bellefontaine, Ohio, in 1893. Also, in that year Stephen Duryea first successfully operated an automobile in this country, and Henry Ford built his first car.

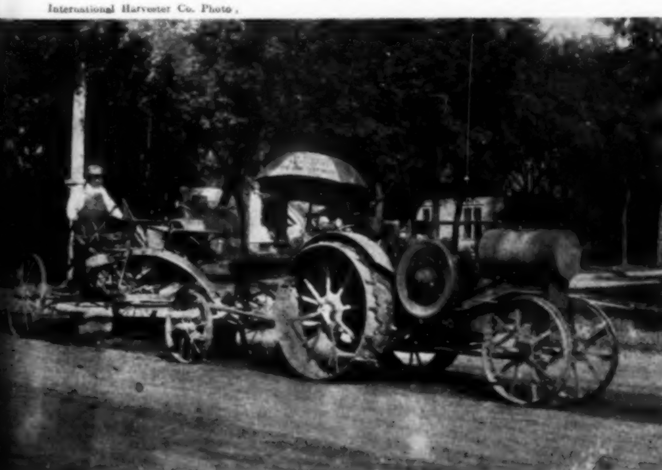
From the beginning of the highway development program, the need for special equipment to perform work became evident. Possibly one of the first devices for road maintenance was the split-log drag for crowning and smoothing the earth road surface. Its initial use is lost in antiquity but it was probably used in this country by the earliest settlers. In Missouri, D. Ward King exploited the use of the split-log drag in the 1890's, and spread its virtues by visiting some twenty-three states, from Maine to Texas and from Maryland to the Dakotas, to promote it as a cheap way to obtain good roads.

The King drag was made of a log, 7 to 9 ft long, split in half lengthwise. The halves of the log were set flat sides to front, and fastened about 30 in. apart. There was a platform on top on which the driver could stand. In 1908, a pamphlet prepared by Missouri's first State Highway Engineer, Curtis J. Hill, M, ASCE, asserted, "the best and most economic implement with which to maintain an earth road is the drag," and estimated the cost at not over 30 cents per mile. The self-propelled power grader of today is an evolution of the split-log drag and is one of the most useful machines for road maintenance.

King, although he gained no special

Left: Gasoline-engine tractor replaced horses for hauling road grader about 1900. **Right:** Modern motor grader, operated by one man and mounted on fully pneumatic rubber tires, is one of most generally useful highway maintenance machines, found in every highway department.

International Harvester Co. Photo.



recognition for it, pressed for adoption of weed control not only on the road shoulders, but on the roadway itself. He noted that weeds and grass held moisture and prevented the road surface from drying out rapidly. Today the weed control program has been expanded to embrace the entire right-of-way.

State Takes Over Maintenance

New Jersey, in 1891, inaugurated state aid for road improvements. Massachusetts adopted the plan in 1893, Connecticut in 1895, Rhode Island in 1896, Vermont in 1898, and so on until all the states had joined in by 1917. Congress on March 3, 1893, established the U. S. Office of Road Inquiry and appropriated $10,000 to carry on research and educational work in connection with road management and construction. This agency grew into the Office of Public Roads and finally the Bureau of Public Roads, which throughout its life has contributed much, not only toward making construction of adequate roads possible, but also toward providing for their proper maintenance.

The New York Enabling Act of 1898 was designed to aid fiancially in the maintenance of the network of earth roads that then existed, and to encourage the abandonment of the antiquated system of working out the road tax. The Federal Aid Act of 1916 provided, among many things, that states must maintain highways on which federal aid was received for construction.

In the early 1900's the nation's expanding economic needs and the increase in the number of automobiles combined to create both a desire and a need for more and better roads. The steam roller and the rock crusher still were the only power tools in general use. Horse-drawn vehicles and hand tools were the rule, and they were becoming far from adequate. Likewise, the long-established rule of local maintenance was proving more and more unsatisfactory. Soon after the New York State Commision of Highways was set up in 1909, it was decided to establish a patrol system to insure constant care and attention to the roads.

To keep up with the changing picture, by 1917 every state in the Union had adopted some form of state participation in highways. Actual building and maintenance still were carried out at the local level in many states, but the procedure was changing form. Trained engineers were taking over the supervisory work, and expert advice was becoming more readily available, and more often sought, as state highway departments were set up and became active agencies.

This same period also brought, in 1914, organization of one of the oldest of America's agencies whose prime goal is better highways—the American Association of State Highway Officials. The AASHO was formed, primarily, to bring together highway officials so that they might discuss and compare their problems, exchange ideas, and promote research. This pooling of ideas and know-how has resulted in invaluable contributions through the years.

The idea of state-controlled road programs took hold quickly and grew. By 1920 several states had adopted it, most of them even going so far as to set up a special maintenance department or bureau to meet mounting needs. In Missouri, for example, the State Highway Department was created in March 1917, and that year brought the first move toward state aid on maintenance. This came as the new board established a policy of paying $1.25 per mile per month for dragging roads connecting county seats of adjoining counties. By 1923 it was found expedient to set up a maintenance bureau in the State Highway Department.

With the organization of maintenance divisions or bureaus came a broadening in ideas and understanding of just what maintenance actually meant. Not only did it mean mending roads, but it began to embrace the marking of them so that travelers could find their way about more readily.

The year 1920 saw creation of the Highway Research Board of the

Left: Typical road patrolman in Missouri, at right, about 1925, operated horse-drawn wagon and hand shovel. At left, R. D. Pugh, then Assistant Division Engineer of Missouri Highway Department, is told, "Traffic is sure picking up—had four automobiles through here yesterday." Right: One of earliest maintenance trucks used by Missouri Highway Department, about 1917.

National Research Council—the accomplishments of which any highway engineer quickly recognizes. That same year brought also a rising cry to lift the nation out of the mud, with many fund campaigns carried out, in Missouri among other places.

Enter Rubber-Tired Equipment

Wars, destructive as they are to human life and property, always have brought some later-recognized contributions toward the advancement of civilization. World War I may be credited with bringing about the beginning of motorization and mechanization of highway maintenance departments, by making available surplus army trucks and tractors. Although the old solid-tired White and Liberty trucks didn't do too well on a country road in wet seasons, they proved the value of such vehicles in the overall picture by speeding up many activities.

Yet, even with those trucks and their hard-rubber tires, or the iron-wheeled and lugged tractor, pulling drags and light graders, the most effective maintenance patrol still was the four-up light team, the light patrol grader, and wagons, slips, and shovels in the hands of husky and willing men. The blade and team smoothed the surface; the slip built up and drained the low spots; the wagon hauled stone, gravel, and cinders to fill soft places, or bridge lumber and culvert pipe as needed.

Manpower was extremely short during the postwar period of the early 20's because jobs were plentiful and pay was high. This condition emphasized the value of equipment in supplementing men and thus helped to speed up maintenance mechanization. The one-man power grader might well be considered the child of the manpower shortage. The need for this piece of equipment developed during the early 1920's, and by 1926 several fairly good motor graders were available, although they were still equipped with spade lugs or solid rubber tires.

The inadequacy of lugs and solid tires was to be the springboard for another advancement that has contributed heavily toward making today's maintenance equipment what it is. That was the introduction of pneumatic tires on road machinery. Again, Missouri can claim some credit for promoting this forward step.

A McCormick-Deering agent sold the Macon division engineer and his maintenance chief on the idea of putting pneumatic tires on a motor grader. This was the first such test by the company, and one of the first, if not the first, in the nation. The new-type tires were put on 10-20 graders. The company assigned a mechanic to stay on the spot and work out the bugs, of which there were plenty. But by the end of the year the pneumatic-tired equipment had proved that it could more than double the mileages of work performed by the old iron-wheeled and solid-tired machines. Most equipment concerns adopted the idea at once.

Bituminous Surfaces Cut Dust

The late 1920's also brought extensive experiments in bituminous road surfaces, many of them done in the maintenance bureau. These experiments resulted from the demand of increasing traffic for elimination of dust on loose aggregate surfaced roads. Limited funds for this work dictated the need for a low-cost dustless surface. In 1928 the Missouri Highway Department purchased its first distributor, rollers, heaters, and necessary crane and trucks for such a program. Retread, oil mat, and other experimental bituminous surfaces were built. Many rock asphalts and patented bituminous mixes were tried, and various grades of tars, cutbacks, and emulsions were used. This period might well be listed as the era of development of low-cost bituminous surfaces, not only in Missouri but elsewhere. With the development and widespread use of bituminous pavements and surfaces came the necessity of devising new maintenance methods to care for such roadways.

Despite depression handicaps in the 1930's, that decade saw some outstanding contributions toward perfection of maintenance methods and activities. Our department in 1929 developed and built a truck-mounted road magnet and operated it over all state gravel roads to remove metallic articles capable of puncturing tires. During 1930 this machine covered 7,212 miles of roads and picked up 27,033 lb of metal such as nails, screws, and bolts. The device prevented many a tire puncture and gained much favorable publicity throughout the state and the nation. Even today such magnets are in demand and are operated over rural roads in Missouri.

In addition, this decade brought even more attention to controls on vehicle weights, vast expansion in bituminous road surfacing, and greater emphasis on maintenance of secondary or farm-to-market roads.

Undersealing Replaces Mud-Jacking

Mud-jacking of pavement slabs was introduced early in the 1930's. In its initial phase, mud-jacking was practiced to pump a soil-cement water mixture under pavements to raise sunken areas, and thus restore the smooth riding surface. Now the

(Continued on page 248)

This modern $1^1/_2$-ton dump truck is typical of units used by all highway maintenance men today.

Photos by Courtesy U.S. Bureau of Public Roads

The changing picture in highway traffic

D. GRANT MICKLE, M. ASCE

Director, Traffic Engineering Division, Automotive Safety Foundation, Washington, D.C.

Two scenes on New York's Fifth Avenue are separated by 38 years. Street facilities remain the same; only the type, speed and composition of traffic have changed. Easter Sunday morning in 1900 is contrasted with Easter Sunday morning in 1938.

The demands of modern automotive traffic have, in effect, revolutionized the mission of highway engineering, as traditionally accepted since the days of antiquity. In the current philosophy, the highway is not merely a structure to permit movement; it is a productive facility, whose output in transportation is measurable in both quantity and quality. The basic objective is no longer to create roads, or even mobility, but the safest, fastest and most economical transportation possible.

Through the centuries, and into the early period of the automobile, the engineering approach to the highway problem was almost exclusively structural. The advent of the high-powered motor car changed all that. The functional requirements of the new type of traffic swiftly came to the fore. There began a progressive shift from the static aspects of road design to the dynamic factors that bear on free-flowing movement. Opportunities to apply engineering skills broadened to an undreamed-of degree as the volume, speed and composition of motor traffic generated a welter of complicated new problems.

Since the major part of our key systems of roads and streets were built to design standards prevailing under the old philosophy, it is not surprising that we seem to face a perpetual traffic crisis. This is no reflection on the technical competence or the practical achievements of the men who engineered the basic road plant. In little more than three decades, they accomplished the almost superhuman feat of extending our surfaced mileage from a few thousand miles to over a million and a half. Without this engineering conquest of sheer distances, the spectacular growth of automobile use in the United States could never have come to pass.

No one could have foreseen back in 1920, when the large-scale road program got under way and when the number of motor vehicles in the United States was only around 9 million, that by 1952 the total would skyrocket to 52 million. There was no indication that the truck, a comparative novelty in the early twenties, would become such a vital factor in the transportation system that it would multiply to today's 9 million. Between 1940 and 1951 alone, truck travel increased 165 percent; and of this movement, fully 75 percent was accounted for by combinations of the truck-trailer type, and only 25 percent by single units.

The road and street network was never designed to accommodate the

half-trillion or so miles a year which our motor vehicles are now rolling up, or to cope with the extremely diversified and complex traffic patterns embraced in this astronomical travel mileage.

Basic Problem Is Lack of Capacity

Critical lack of capacity on rural trunklines and urban arterials lies at the root of much of our present highway dilemma. This is apparent from the fact that 86 percent of all highway travel occurs on less than one-fourth of our rural road mileage. Half of the total annual travel is concentrated on city streets, which comprise only one-tenth of the road network. The latter, of course, explains why virtually every one of the 168 metropolitan areas in the nation has become a chronic traffic bottleneck.

Structurally, the bulk of our older roads and streets are still fairly sound. Capacity-wise, many of them were already obsolete before World War II. A huge backlog of needs was piled up during some 15 years of depression and war, when the facilities were not properly maintained, rebuilt or expanded. Now, with scarcely a breather, our highway agencies are faced with inflated costs and shortage of materials to carry forward a program commensurate with civilian and defense transportation requirements.

In the cities, the street capacity problem is usually aggravated by a more or less acute shortage of off-street parking space; in rural areas, it is compounded by a wide variety of design deficiencies. The growing inadequacy of the street and highway plant exacts heavy penalties in blood and dollars. The 1951 accident toll was 37,500 killed and a million and a quarter injured. The economic waste entailed in these mishaps was estimated at $3.5 billion.

It is believed that over-all losses from congestion and parking shortage even exceed those of traffic accidents. These losses are reflected in rising vehicle-operating costs, urban blight, depressed realty values, decreased city tax revenues and decline of downtown business centers. For example, a few years ago the Regional Plan Association of New York declared that traffic delays were costing the city's business men over $300 million annually. Before World War II, Detroit figured its congestion losses at $10 million a year. St. Louis set its losses from congestion and accidents at $125,000 a day. Boston was said to be losing $40 million a year in trucking business because of traffic conditions.

In terms of today's dollars and unprecedented travel volumes, current losses are doubtless even more staggering. Unfortunately, no broad-gage study of the multiple costs of congestion has ever been undertaken. However, the far-reaching study of parking economics recently launched by the Highway Research Board, at the Universities of Michigan, Ohio, California and Washington, should shed a great deal of light on losses due specifically to insufficient parking.

The intolerable waste and inconvenience caused by traffic inefficiencies have served to focus increasing attention on the operational aspects—both in the design of new facilities and in the utilization of existing roads and streets. It has become clear that highway planning, design and operation are integral parts of the total engineering problem, and that functional principles cannot be ignored without grave jeopardy of the public interest.

Hence the modern engineering approach strives to keep in perspective the relation of geometric details to the amount, behavior and speeds of the traffic the road must carry. We know now that the fullest possible understanding of the desires and abilities of drivers, the characteristics of their vehicles—and the definite limitations of both—is prerequisite to sound construction and operation.

New Frontiers of Fact-Gathering

To translate this new thinking into operational procedures applicable to specific traffic requirements obviously called for engineering study and technical supervision. Thus new frontiers of scientific fact-gathering were opened up, new techniques for the collection and analysis of traffic data created. With the quantitative and qualitative information developed through these new methods, it became possible not only to determine where the traffic goes, but where it *wants* to go, and where it will probably go in the future. This type of data has become the core of long-range highway planning. The origin-and-destination study, in particular, has proved invaluable for determining present traffic patterns and future trends (Fig. 1).

Volume studies turn the spotlight on the size and composition of the traffic stream, the types of vehicles and vehicle loadings, the numbers of pedestrians, and the periods of minimum and maximum flow. As a result of accident studies, it became clear that accidents are symptoms of inefficient transportation, and not the inevitable toll of motor-vehicle use. By establishing the locations, times, circumstances, conditions and actions that contribute to mishaps, the findings aid at getting at the root causes.

Similarly, time and delay studies probe into the factors that contribute to traffic disorders and interruptions, which not only fray the nerves of the motoring public but hit its pocketbook by causing time losses and increased vehicle-operating costs. Parking studies measure the demand of storage space both on and off the street, and the availability of parking areas in relation to principal destination points of vehicle trips. Research in recent years has also developed a variety of new parking equipment and structures, including meters and mechanical garages.

Farm Security Administration Photo

Application of one-way street principle in Detroit brings order into heavy traffic.

Dollars-and-Cents Implications

One important result of this diversified fact-finding is that gradually the public is being brought to understand the dollars-and-cents implications of

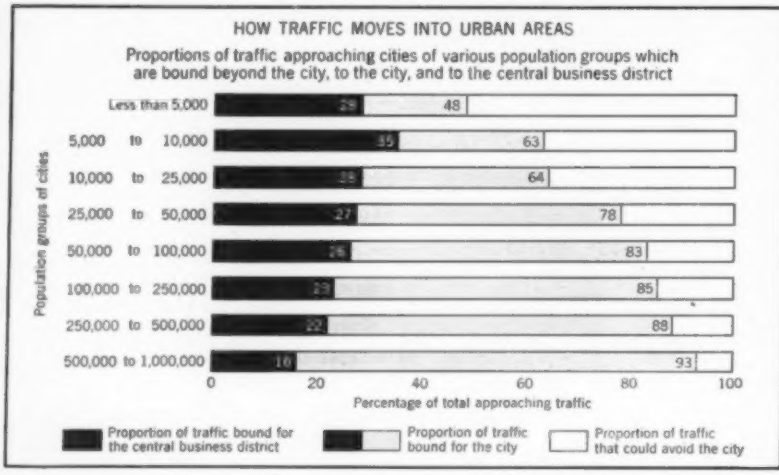


FIG. 1. Origin and destination studies have proved invaluable in determining present traffic patterns and future trends.

bad traffic conditions. Therefore, in addition to their other values, traffic studies have become a vital means of securing public support for essential improvements.

The era of comprehensive traffic research was ushered in when progressive highway administrators decided that the trial-and-error methods and expedients of the past would never provide solutions for the com plex problems of motorized movement. In the early twenties a few states, notably Ohio, and several large cities, including Chicago, Pittsburgh and Seattle, began to assign engineers to the collection and analysis of traffic facts on a full-time basis. The U. S. Public Roads Administration (now the Bureau of Public Roads) initiated a series of fundamental traffic studies about the same time, and several universities undertook similar research. In 1936 the state planning surveys, conducted jointly by the states and Public Roads on a continuing basis, began building up a vast reservoir of valuable transportation knowledge.

The technical studies brought to the surface many of the underlying weaknesses in the highway transportation system, formerly either overlooked or misinterpreted. For instance, it had been commonly believed that the great bulk of traffic approaching on main rural roads wants to avoid cities. Origin-and-destination surveys emphatically disproved this, and showed that attempts to relieve urban street congestion by routing around medium- and large-sized cities were by no means the complete answer. It had been assumed, also, that most of the traffic that enters cities was headed for the central business district. Studies revealed that up to 50 percent of the downtown volumes are merely passing through, for lack of more direct distribution routes (Fig. 1).

Formerly municipal officials looked upon street widening as a sort of cure-all for street congestion. Research brought out that the real bottleneck is the intersection, and that merely broadening a thoroughfare did not correct the basic cause of jamming. Moreover, it was indicated that cities which spent substantial sums in widening major streets could have obtained the same or even better results by eliminating the space waste and traffic disorders due to indiscriminate parking at the curb.

In searching for reasons for the preponderance of night-time accidents, it became apparent that many street lighting systems had been designed with too much emphasis on beautification and too little on safety. Most of the illumination, instead of being directed onto the pavement, was being thrown into the air.

New findings revised old theories about the relation of speed to accidents. Setting of arbitrary limits, usually without engineering determination, was having no perceptible effect on the accident curve. Speed in keeping with conditions, rather than a general slow-down of motor vehicles, became a more realistic objective of control—especially since in the public mind the velocity of the automobile is one of its prime assets.

Similarly it became clear that misuse of traffic control devices and other regulatory measures was not only widespread, but was adding materially to the traffic confusion. It began to be recognized that a badly timed signal light or a poorly placed traffic sign can do more harm than good; or for instance, that because of unsound routing, the place where transit vehicles must make a turn can become the focal point of a perennial traffic snarl.

In short, the cardinal lesson taught by the factual studies was that efficient traffic operations are impossible without the guidance of tested engineering principles.

Up to that time, the handling of such operational tasks as were then being performed was regarded as a phase of enforcement. Historically the job had been delegated to the police as just another chore in connection with keeping order on the streets. When the swelling tide of

Overhead signals on New Jersey approach to Holland Tunnel leading to New York City permit separate control of each lane, so that heaviest traffic can have additional lanes.

The Port of New York Authority

motor vehicles began to swamp police efforts to improve chaotic traffic conditions, it became obvious that regulatory measures were not enough.

In the past it had been believed that the only alternative was resort to capital improvements like street widening or other major construction. Since cities particularly are as a rule hard pressed for highway funds, the prospect for early traffic relief was none too encouraging. The activities of the small group of men who were pioneering in the application of engineering techniques to traffic problems in different parts of the country drew public attention to a new alternative. Through careful technical analysis of specific traffic difficulties, followed by scientific treatment embracing a variety of traffic aids, these individuals were demonstrating that a simple and economical remedy could often serve almost as well as an extensive redesign job or a new roadway.

Gradually it came to be realized that practical solutions must come largely through the positive resources of engineering. The next logical step was to give formal recognition to the fact that traffic operation is properly one of the important technical functions of state and municipal government.

To insure continuity for an effective program of research and operations, some state highway departments initiated special units within their organizational structure. In certain cases the traffic engineering functions were integrated with the maintenance division, in others with the planning survey. The units which proved most successful, however, were those set up as an independent division having both study and operational responsibilities. Progressive cities, too, began to adjust their street management structure to give full scope and continuity to traffic engineering activities.

By 1946, most of the states had established traffic engineering divisions. A survey conducted by the Eno Foundation showed that in only four states were these functions still handled by the highway police, and in four others by maintenance engineers.

The sampling of cities revealed that all those of over 500,000 population, and 67 percent in the 100,000–500,000 group, had traffic engineering units. The ratio in the smaller cities was 48 percent in the 100,000–200,000 group, and only 32 percent in the 50,000–100,000 group. In most of the communities which reportedno traffic engineering agency, the functions were under police jurisdiction, or shared with the engineering division or electrical bureau. In a few instances, the responsibilities were handled by the department of public works or safety.

The emergence of traffic engineering as a specialized field of highway engineering created a growing need for trained technicians to give full time to operational aspects and related problems of planning and design. In 1926, with financial aid provided by Paul G. Hoffman and other leaders of the automotive industry, a national center for traffic engineering research and training was established at Harvard University. In 1938 the program was transferred to the Yale Bureau of Highway Traffic, with expanded support of industry groups channeled through the Automotive Safety Foundation. To date, nearly 300 engineers have received graduate training under this program, and hundreds of others have received short-course instruction at numerous other universities. Today, the paramount need is for more rapid integration of basic operational principles into highway engineering courses given at all engineering schools.

Just as a hundred years ago civil engineers found it desirable to form the American Society of Civil Engineers, for the interchange of information and the advancement of their professional field, so did the practitioners in the fledgling field of traffic engineering find it advantageous to band together as the Institute of Traffic Engineers in 1930. This comparatively new technical society, with headquarters at Yale University, functions as a central agency for correlating and disseminating factual information and techniques developed by members of the profession and for the development of operational and administrative standards.

The duties of the traffic engineer have vastly enlarged during the past quarter century. In the early days his job began only after the planners and builders had finished their work, and then he devoted virtually all of his research to traffic control and accident reduction. Operationally, most of his efforts were devoted to putting up traffic signs and stop lights and installing pavement markings where accidents and congestion indicated some physical deficiency.

In the state highway department, responsibilities of a division of traffic engineering now include the gathering of essential traffic facts, including accident analysis; the review of highway design to insure proper geometric detail; installation of warning and directional signs and route markers; installation of signals at high-volume intersections; and marking of centerlines and no-passing zones. Also within the scope of the state traffic engineer is the determination of speed zones and control of roadside exits.

In addition, the state traffic engineering division frequently provides consulting service to cities and counties within the state, and conducts urban origin-and-destination surveys and studies of parking demand. Traffic engineers have played a prominent part in statewide engineering studies of highway need in some 25 states.

Urban Problems Insistent

But the greatest vineyard for the traffic engineer's labors is in the cities. Fifty years ago three out of five Americans lived in rural areas; today it is just the reverse, with more than three-fifths of the population located in urban communities. Over 80 percent of the nation's population gain in the past decade occurred in our metropolitan areas. This growing concentration of people, and their increasing dependence on the motor car in their daily pursuits, is one obvious reason for the worsening traffic plight of our cities.

It has been said—without too much exaggeration—that our cities

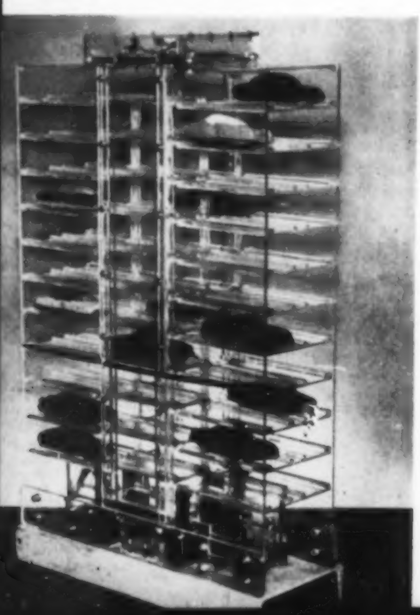
Signs clustered as at left, below, are impossible to read at normal speeds, in contrast to simple signs, below right. Typical example at left, intersection of U. S. 206 and U. S. 130 in New Jersey, indicates need for drastic revision in sign-marking procedures on rural highways.

Photos by Courtesy U.S. Bureau of Public Roads

have been trying to make eighteenth century streets serve twentieth century traffic. The gridiron street pattern common to most of our communities, with its characteristic frequency of intersections, was never ideal even for horse-drawn traffic, let alone today's tremendous volumes of high-powered motor vehicles. Add to this fundamental handicap the acute shortage of off-street parking and truck-loading space, and it is easy to see why unsnarling the city's traffic jam is a monumental challenge. Pedestrian conflicts, cross-traffic and turning movements, curb-parking maneuvers, and the mixing of private, commercial and transit vehicles make congestion and accidents almost inevitable.

In this situation, it becomes imperative to make a realistic appraisal of the existing street plant to determine whether or not it is being used to maximum advantage, and if not, how the full service potential of the facilities can be obtained. In cases where main urban arteries are taxed beyond their absolute capacity, the only solution is expressway construction or other capital improvements. But we know that, by and large, the present street system will have to continue to serve for a long time to come. This leaves no alternative but to find ways and means to reduce physical hazards and utilize available riding surface to the utmost.

Partial model of push-button automatic garage developed by Automatic Storage Corp. of Detroit, shows how cars move in cages up and down in double elevator shaft and across top and bottom. Initial structure to be built in Detroit will park 100 cars on 10 floors.



The recognized procedures of traffic engineering can be used to correct an amazing number of weaknesses in the street plant. Not only are these measures, for the most part, relatively inexpensive, but many of them result in benefits which are both immediate and lasting. Some of the techniques have been newly developed; others are adaptations or refinements of practices that pre-date the automobile, and in some instances go back to ancient times.

For instance, safety islands for pedestrians were already common on the streets of London and Paris in the 1860's. Road markers were used abroad for many centuries, and in America from Colonial days. Our frontiersmen blazed trees or bent saplings to mark their trails, and ancient peoples often piled up stones as trail markers. At the time the "horseless carriage" first became popular in the United States, state route numbers were often painted on convenient barns, bridge railings and telephone poles.

Because the streets of Imperial Rome were narrow and congested, the Caesars established the first one-way movement in recorded history. Parking restrictions go back almost as far, as evidenced by a law in old Pompeii which forbade chariots to stop on the road for loading. In England, regulations of 1660 vintage prohibited the parking of hackney coaches on the King's Highway. Albany, N. Y., passed an ordinance in 1697 to limit the speed of horse-drawn vehicles and horseback riders. While the first traffic survey in this country—a study made in New York to determine customary curb parking distances of motor vehicles—was conducted as early as 1910, the origin-and-destination study is a relatively recent development.

At any rate, numerous cities have substantially increased their street capacity, opened up critical bottlenecks, eliminated recurrent traffic disorders, and reduced their accident rate by carrying forward an intelligent and up-to-date program of operational measures.

Chicago offers a classic example of beneficial traffic engineering treatment. As early as the twenties, congestion reached intolerable proportions on State Street, in the Loop District. A threefold program was put in operation: curb parking was banned, left turns were prohibited, and signal lights were coordinated to keep traffic moving. The combination of these steps brought prompt relief, but more than this, the street has remained comparatively uncongested ever since, despite heavy increases in traffic.

Detroit's Grand River Boulevard, one of the nation's busiest streets, carrying upwards of 60,000 vehicles daily, formerly suffered from perennial clogging and an inordinately high accident rate. Frequency of left turns rendered the two inner lanes of the six-lane pavement virtually useless as carriers of arterial traffic to and from the city. Prohibition of left turns throughout the 14-mile length of the thoroughfare, off-center lane usage during peak periods, a modern progressive signal control system, and banning of curb parking between certain hours, have served to achieve maximum capacity. Running time has been cut by nearly 12 minutes and accidents have been materially reduced.

Extensive use of the principle of unbalanced lane flow has made it possible for Los Angeles to carry fantastic volumes of traffic into and out of the central business area on existing streets. Currently, with the completion of the freeway system into the downtown section, a one-way plan is being worked out so that the anticipated high-density traffic can be collected and distributed with ease and dispatch.

Failure to make more use of operational techniques in many cities is ascribable to official failure to understand the importance of street transportation or the magnitude of the losses engendered by bad traffic conditions. Most cities spend only a fraction as much on traffic-accident prevention as on fire protection. Yet in monetary terms—as well as in total lives lost annually—traffic accidents are a vastly greater menace.

About 1938 Toledo, Ohio, released a report which indicated that one year's traffic accident losses amounted to $1,022,325, as compared with fire losses totaling $311,802—a ratio of three to one. Nevertheless during that same year, according to the report, for each dollar of traffic-accident loss, only 34 cents was expended for traffic control and betterment services, while two dollars was allotted to the fire department for each dollar of actual fire loss.

Another factor which militates against an effective attack on the traffic problem in many cities is weakness in administration. Manifestly, relieving our strangling communities through freer circulation—in the face of antiquated streets and record-breaking travel volumes—poses a supreme test of sound management. In the majority of cases, however, the organizational structure for ad-

Difficult traffic conditions result from expansion of industrial facilities without comparable development of street and parking facilities.

Minor physical improvement of relatively unused section of wide intersection in Washington, D.C., provides for loading of mass transit.

ministering the facilities is as seriously deficient as the street plant itself. Scattered responsibilities, split authority and scrambled organization seem to be the earmarks of this vital phase of public administration.

In the case of the older municipal services, such as water supply, welfare and public works, unity of the managerial structure and centralized authority are provided for in the city charter. Few cities have given charter recognition to street and traffic administration as a major municipal function, with the attention and stature accorded to the long-established departments.

Instead, responsibilities in this area have been parceled out, as occasion arose, among existing city agencies. Such diffusion naturally results in divided powers, duplicated effort, conflicts, and other inefficiencies. Desirable physical improvements, even those of a minor character, may get hung up indefinitely as the proposed project is shuttled back and forth from one municipal agency to another. Moreover, proper correlation of physical improvements and traffic operations becomes a virtual impossibility.

An all-too-common result of this glaring administrative weakness is the failure to make a specific agency responsible for the development, design and programming of a master street plan. Without a master plan—and the authority to carry it forward—it is hard to budget expenditures prudently for even individual projects, not to mention a comprehensive street program.

Traffic is a decisive factor with respect to locations and mutual rela-

Great improvement was realized at corner on Sheridan Road, Chicago, by throwing lane use off-balance under peak traffic conditions.

tions of the various community activities. The master plan, therefore, can exert a powerful influence in defining neighborhoods, stabilizing land values, integrating the different modes of transportation, controlling abnormal decentralization, and rectifying the jumbled land uses which have generated so many of the headaches of the average city.

Lack of a centralized street and traffic agency also makes it difficult for the city to carry on effective liaison in highway matters with other jurisdictions. That is an important consideration, since modernization of arterial routes often demands cooperation of other levels of government—county, state, and federal. The present setup of most municipal street agencies provides no focal point for effective inter-governmental relations, which of course are essential not only in planning of facilities, but in joint financing, acquisition of rights-of-way and contract letting.

The rapid growth of suburban sections in recent years emphasizes the necessity of the area-wide approach in municipal thinking and planning, whether the objective be improved transportation or some other sphere of civic interest. To preserve the economic health of parent cities and foster sound development of the fringe communities will require the utmost in harmonious adjustment of transportation, land use zoning, traffic laws and controls, and administration.

An encouraging sign is the recent action taken by a few larger cities, notably Detroit and Philadelphia, in consolidating some of the basic functions of street and traffic management. Because of the vital importance to every city's economy, street transportation deserves major attention, and this can best be achieved through integration in a single department of those functions pertaining to the planning, construction, maintenance, and operation of the street system. It appears certain that in the future more and more cities will assign these functions to one agency and insure continuity by giving it charter status.

Accelerated Effort Foreseen

Looking ahead, the spacious modern motorways that have begun to make their appearance in a few of our leading cities will some day be part of expressway networks that will lace broad metropolitan areas. By the same token, we can expect that the sheer volumes of motor traffic will give impetus to an accelerated effort in making better use of existing facilities.

This will involve more productive methods of lane usage and reversal of the direction of traffic during peak periods by signal control. Instead of lane efficiencies of only 20 and 30 percent, as now developed on many of our urban arteries, service approaching the high efficiency ratio on expressway lanes will be sought and probably obtained.

Surface arterial streets will be converted to semi-limited access facilities by closing minor cross-streets and controlling turns at major intersections. Progressive signal timing, giving preferential treatment to the direction of principal traffic flow at different times of the day, will also be employed far more than at present.

Modern signal-control methods will be a "must," and electronic devices may be used to change signal cycles several times during the day to accommodate shifting patterns of traffic movement. Even radar or modified television may be adapted for use at strategic points to advise a central dispatching office of unusual traffic tie-ups, so that emergency measures can be taken promptly.

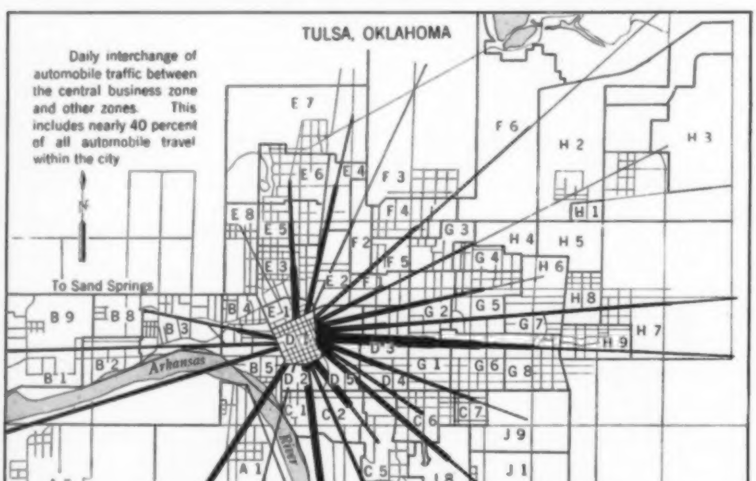
Parking on the street will disappear, and off-street parking structures will sprout plentifully in the downtown sections. Mechanical garages will be commonplace; devices for parking vehicles will become just as much a part of business facilities as the elevator and the escalator.

In rural areas, spot treatment will provide extra lanes on steep grades for commercial vehicles. Roadside controls will be much more extensive, and signing will be modernized for greater visibility and convenience.

We are, without question, on the threshold of a transportation era when automotive travel will exceed anything previously visualized. Our present traffic volumes have already outrun the volumes predicted for 1960. In terms of number of motor vehicles, we are ten years ahead; in terms of roads and streets, we are at least ten years behind. We cannot afford to lose sight of this fact, since the highway system is the backbone of our civilian economy and our national defense. This is a great challenge to all citizens. To the engineer, it is both a challenge and a tremendous opportunity. For to serve the nation adequately in the critical years ahead, highway transportation must be made safer and more efficient than ever before. And the only way to do that is to put highway transportation on a sound engineering basis.

(This article was prepared from the paper by the author presented at the Highway Division session presided over by Wm. N. Carey, Jr., Secretary of the Division's Executive Committee, at the Centennial Convention in Chicago.)

Chart superimposed on map of Tulsa, Okla., shows how traffic facts, collected through origin-and-destination studies, serve to guide planning of travel facilities.



LAWRENCE V. SHERIDAN, M. ASCE

Planning Consultant, Indianapolis, Ind.

Our expanding cities demand good planning

The expansion area beyond the corporate limits of cities is the arena where haphazard growth and planned orderly development constantly conflict. In this arena the future convenience, economy, attractiveness, safety, and welfare of the expanded community will be determined. The best possible master plan is essential to insure development based on sound principles of growth rather than random expansion. Both the strategy concerned with the promotion of the kind of community which is desired and the tactics whereby the desired objectives can be attained are essential elements in the planning leadership of the expanding city.

In the days of short-range transportation by horse-drawn vehicles, supplemented in only the larger cities by suburban rail service, boundaries were expanded gradually, but in the era of electric interurban service, preceded by the extension of street railways, development became more widespread. Automobiles and extended municipal bus routes transformed the expansion area into an arena of great depth into which have been thrust many scattered developments often loosely connected by thoroughfares, utilities, and services. Thus, strategy and tactics have been altered through the years and far greater understanding of both the possibilities and the probabilities of the expansion area is essential if planners are to direct the growth of the city over the area.

Formerly the probable areas of expansion could be predicted with confidence but, with modern transportation, developments are likely to occur at points quite distant from the city boundaries and in various directions. This situation indicates the desirability of a more widespread basic plan designed to provide a guide for development in any outlying district. (See the master plan for Lebanon, Ind., and its jurisdictional area, following page).

The states have recognized the need for such a far-reaching comprehensive plan by authorizing cities to prepare master plans extending varying distances beyond the city limits. Some states have permitted counties to draw up plans for the development of areas beyond the city limits, and a few have appointed regional or metropolitan planning commissions to cooperate in the development of plans. However, the greatest responsibility for planning the expansion of the city devolves upon the city itself.

Concurrently with the determination of the probable extent of the expansion area, it is essential to consider the limitations that may be imposed on growth due to lack of available water supply. In many cities industrial growth is virtually impossible because dependable water supply in adequate quantity is not available either from ground sources or by storage. Other types of utilities can be provided, but water is a basic natural resource and the building up of an adequate supply involves, in itself, a high degree of planning.

Modern trends of growth are evident throughout the nation and do not vary greatly with geography. Trends in the expansion areas of cities include the following:

Residential

- Larger suburban properties
- One-story residences on large lots
- Grouping of apartments with spacious grounds in suburban areas
- Planned groups of small homes on reasonably large lots
- New town and community developments, including complete neighborhoods

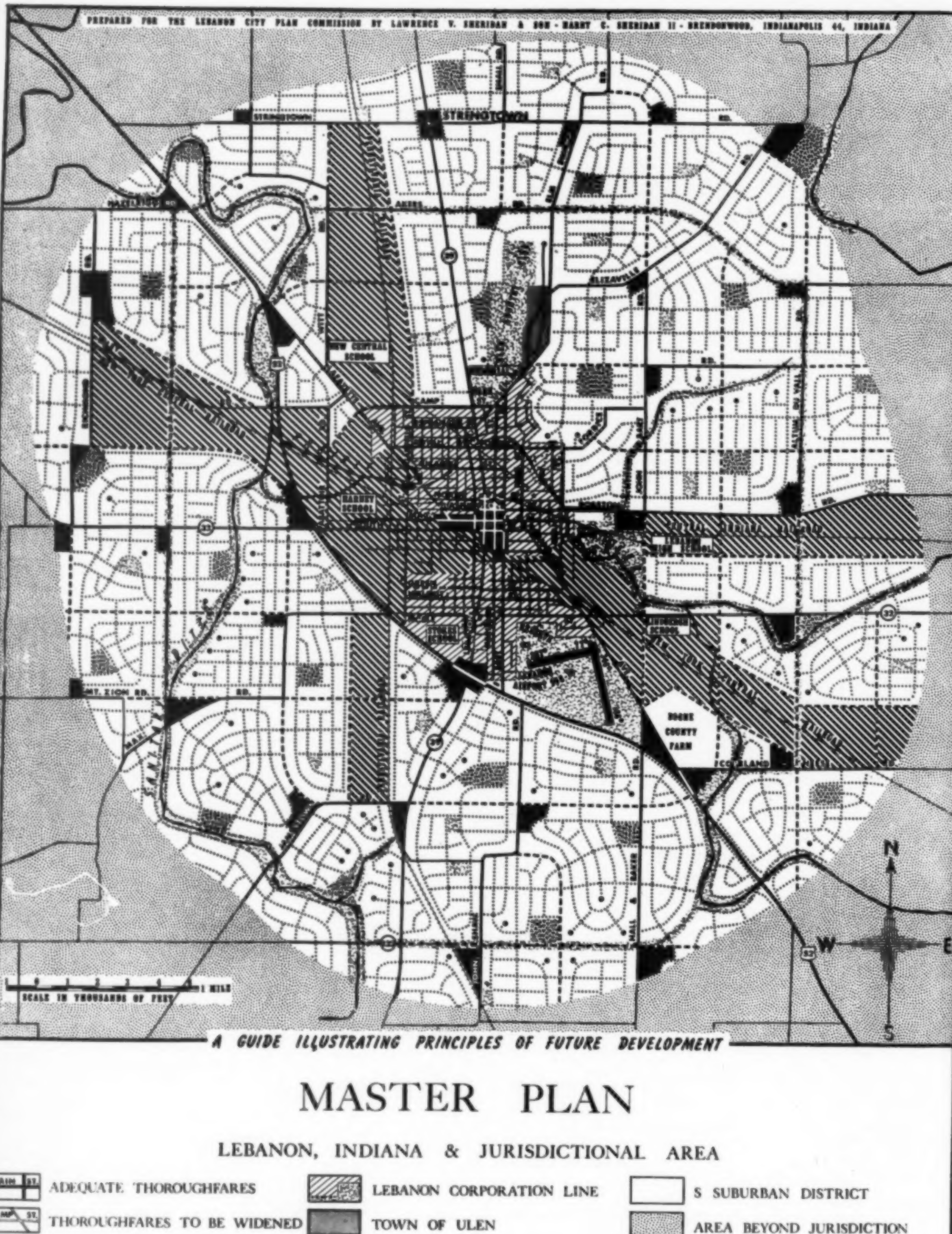
Commercial

- Grouping of stores in neighborhood and community shopping centers
- Provision of adequate off-street parking facilities
- Attractive architectural and landscape design of shopping centers
- Planning of shopping centers as integral parts of neighborhoods

Industrial

- Decentralization of industry into smaller units in medium-sized cities
- Location of new industries on suburban sites and in restricted industrial subdivisions
- Location of industrial buildings on large areas with adequate off-street parking facilities and loading and unloading provisions
- Use of one-story structures to facilitate assembly-line operation
- Greater attention to architecture of structures and landscape treatment of grounds
- Recognition of advisability of preserving industrial districts as essential parts of the community
- Increased use of highway transport, permitting more widespread location of industrial districts

As a prerequisite to planning it is essential to know the type of land use likely to be required in order to conform to the recognized trends in a particular city. Public acceptance of the master plan for the expansion area and its consequent use as a guide for development will depend to a large extent on whether or not it is logical. The public generally realizes consciously or subconsciously, why the city is the kind of city that it is—whether it is primarily industrial, residential, commercial, or a combination of these elements. The plan must recognize the probable oppor-



PREPARED FOR THE LEBANON CITY PLAN COMMISSION BY LAWRENCE V. SHERIDAN & SON - HARRY C. SHERIDAN II - BRENDONWOOD, INDIANAPOLIS 44, INDIANA
NEW CENTRAL SCHOOL
BOONE COUNTY FARM
SCALE IN THOUSANDS OF FEET
1 MILE
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E
A GUIDE ILLUSTRATING PRINCIPLES OF FUTURE DEVELOPMENT
MASTER PLAN
LEBANON, INDIANA & JURISDICTIONAL AREA
ADEQUATE THOROUGHFARES
THOROUGHFARES TO BE WIDENED
PROPOSED NEW THOROUGHFARES
PROPOSED PARKWAYS
SUGGESTED STREET PATTERN
LEBANON CORPORATION LINE
TOWN OF ULEN
AREA ZONED COMMERCIAL
AREA ZONED RESIDENTIAL
AREA ZONED INDUSTRIAL
S SUBURBAN DISTRICT
AREA BEYOND JURISDICTION
PARK & RECREATIONAL SITES
SCHOOL SITES
PROPOSED AIRPORT RUNWAYS

tunities for the economic expansion of the city, estimate the space requirements for various types of development, and provide a generous factor of safety, particularly for industrial land areas.

The specific characteristics of expansion areas vary with respect to topography, highway patterns, locations of railroads and waterways, public and private ownership of land, and in other ways. The size of the expansion area varies in proportion to the size of the city, but only rarely should the area be less then one mile deep and generally it should be two miles or more. In large cities the expansion area may be several miles deep, and where several cities are involved, such as in the Calumet Region of Indiana, New York City, and elsewhere, the area may involve whole counties.

Land Unsuitable for Development

The first step in formulating the plan is the determination of the boundaries of land unsuitable for development. Unsuitable land includes deep ravines or canyons, natural slopes too steep for structural use, flood plains subject to overflow, low areas which are uneconomical to drain, or areas inaccessible by highway except at high cost. Unavailable areas such as municipal, county, or state parks or forests, public institutions with extensive land areas, permanent airports, and areas already committed to development should also be ascertained. In coastal cities extensive tidelands frequently must be classified as unsuitable.

In many cities the land is comparatively level in all directions and there are no natural barriers to expansion. In most cities there is enough unsuitable land to create a pattern of neighborhoods or communities bordered by more or less permanent green belts. Although areas that are too rough, subject to floods, or otherwise unsuitable for structural development are not subject to detailed planning, they are frequently ideally suited to recreational use and in that respect become an important element of the master plan for the expansion area.

Industrial Zoning

After the overall topographic pattern of the expansion area has been determined, the next step, in normal cities, is to decide on the location and extent of industrial land. The National Industrial Zoning Committee (composed of representatives of ASCE, the American Industrial Development Council, American Institute of Planners, American Railway Development Association, Association of State Planning and Development Agencies, and Society of Industrial Realtors) has presented the following twelve principles of industrial zoning:

1. A certain amount of industrial development is required to produce a sound economy.

2. Zoning controls are basic tools in reserving space for industry, guiding industrial location into a desirable pattern, and providing the related facilities and areas needed for a convenient and balanced economy.

3. Industrial use is a legitimate land use possessing an integrity comparable to that of other classes of land use established under zoning and is entitled to protection against encroachment.

4. Through proper zoning, industrial and residential areas can be good neighbors.

5. Industry will continue to grow and most industries will require larger areas in the future.

6. Industry should be reclassified in accordance with modern manufacturing processes and prevailing policies of plant construction so as to determine the desirability or lack of desirability for inclusion in a given area.

7. The industrial potentialities of lands bearing a favorable relationship to transportation should be recognized in the zoning process.

8. Industrial zoning and highway planning should go hand in hand.

9. Special consideration should be given to street layout in industrial areas.

10. Zoning ordinances should be permissive rather than prohibitive.

11. A good zoning ordinance should be sufficiently definite to convey to a landowner a clear concept of what he can do with his land.

12. Industrial zoning can be most effective when considered on a metropolitan basis.

It is clear that the guiding plan for the expansion area should provide plenty of well-located industrial area. Railroads, waterways, highways, and to some extent air transport facilities, existing or contemplated, have a direct bearing on the location of industrial areas.

After the amount of land unsuitable or unavailable for structural development and the extent of industrial areas have been determined, a residue remains which is potentially suited for eventual development into residential communities and neighborhoods.

Importance of Thoroughfares

The pattern for neighborhoods will be established by the arrangement of major thoroughfares, which form the structural framework on which the plan and the eventual development of the expansion area are based. Although basically the major thoroughfares are planned to carry the bulk of traffic for the future community, their location may actually be determined by existing roads and state highways. Other thoroughfares will generally be laid out along section or half-section lines where the land was originally surveyed in sections, and at intervals of one-half mile or thereabouts in other regions. All thoroughfares should be as directly aligned as possible but curved where necessary to fit topography and to secure favorable grades. They should pass around rather than through neighborhoods in order to promote both the expeditious movement of traffic and safety within the neighborhood. Major streets should border industrial districts to promote freedom of development within the industrial district. The thoroughfare plan should be coordinated with expressway, superhighway, or interregional highway plans within the central city, and intercity requirements should also be considered.

Bypass or belt thoroughfares will be located as required in the expansion area. Nearly every community benefits from a circumurban highway intersecting all approach routes into the city, whereby both local and through traffic may avoid the congestion of concentrated areas. Belt highways and other bypasses may be coordinated with parkway developments along stream courses or areas determined to be unsuitable for structural development. Widths of right-of-way for major thoroughfares should be adequate to provide the maximum anticipated traffic capacity although development of roadways may take place in stages. Finally, the pattern of major thoroughfares established in the master plan should agree reasonably closely with the final locations for both alignment and right-of-way widths in order that the planning of neighborhoods may proceed with confidence.

Neighborhood Plan

Neighborhoods formed by the major thoroughfares will be occupied gradually as the city expands. As each neighborhood is developed, the broad conflict between the forces of haphazard growth and those of planned orderly development constantly occurring in the expansion area breaks down into hand-to-hand or, in this case, acre-to-acre engagements. Piecemeal action in the planning of the neighborhood is generally disastrous, inconvenient,

uneconomic, and unattractive. The creation of successful neighborhoods can be assured only by a coordinated planning effort for the entire area.

Technical guidance in neighborhood design goes beyond actual site plans into the field of coordination—convincing owners and developers of property that pooling their interests in the adoption of an overall plan for the neighborhood not only will result in a finer community but will be of economic value to each party.

The principles underlying the creation of desirable neighborhoods are well understood. It is generally agreed that people desire pleasant, safe, healthful, convenient, and attractive places in which to live, and the neighborhood therefore requires the following fundamentals:

1. Building lots with adequate yards and open spaces.
2. Dwellings of sound construction with modern facilities.
3. Zoning and deed restrictions to protect the character of the neighborhood.
4. Major thoroughfares providing convenient access to places of work, commercial centers, and other neighborhoods, but bordering rather than passing through the neighborhood.
5. Neighborhood streets conveniently serving the area, discouraging heavy, speedy and unsafe traffic, and so adjusted to the land as to produce superior building sites and to create favorable grades on streets.
6. A grade school within one-half mile and a junior high school within one mile of all residents accessible with maximum freedom from traffic hazards, and a senior high school accessible by thoroughfares.
7. Playgrounds—with minimum areas of 10 acres adjacent to grade schools, with minimum areas of 5 acres for small children within the neighborhood, and with minimum areas of 25 acres near the junior high schools.
8. An athletic field conveniently close to the senior high school.
9. A park with a minimum area of twenty acres within one mile of the neighborhood.
10. A community center for indoor recreation and cultural activities, within one mile of the neighborhood, which could be combined with the neighborhood park or school facilities.
11. Larger parks or reservations with many types of recreational facilities nearby.
12. A community shopping center within one mile, providing a wide range of stores and adequate off-street parking facilities, planned as an architectural unit with appropriate landscape development and with stores grouped rather than strung out along the streets.
13. Convenience stores conforming to community shopping-center standards within one-quarter mile of all residents.
14. Freedom from deteriorating features, such as obsolescent or substandard housing, intrusion of misplaced commercial or industrial structures, and lack of storm drainage or flood protection or sanitary facilities, and freedom from the nuisances of smoke, gas, odors, noise, and other noxious features.

Whereas the major thoroughfare plan is a rigid plan because the rather exact location of future major streets must be determined far in advance, the neighborhood pattern is flexible as long as it does not violate sound principles. Developers may have varying ideas as to how the neighborhood should be planned, and individual initiative should be given full sway. The aim of the planner's technical guidance is to point out clearly various principles and methods by which good neighborhood designs can be accomplished and to bring about the necessary coordination of effort. The planning authority charged with the responsibility for technical guidance should make a thorough study of the expansion area and prepare a neighborhood development plan that provides both a street pattern suitable to the terrain and a unified layout for each future neighborhood unit.

The neighborhood development plan should also indicate general locations for schools, parks, play grounds, shopping centers, and other facilities. To assist developers, it may appropriately include examples of successful designs of streets, housing, schools, parks, playgrounds, shopping centers, street signs, and various appurtenances, supplemented by cost and economic data to prove the value of certain designs. If based on accurate topographic maps or aerial photographs used with a stereoscopic viewer, the neighborhood plan will prove to be very accurate and thus more valuable as a guide.

Master Plan for Area

As a final step, the master plan for the entire expansion area attempts to stimulate the imagination and initiative of property owners and developers so that coordination and the creation of better neighborhood plans may result. Each phase of the master plan should acquire validity and force by official adoption.

Most states have authorized cities to prepare plans for their own expansion areas. These plans generally are the work of the city plan commission, subjected to public hearings and discussions, and finally adopted by ordinance of the city council or governing body.

Master Plan in Four Parts

The master plan would normally consist of four parts:

1. A land-use or zoning plan designating areas for residential, commercial, and industrial use, providing for the regulation of density of population and intensity of land use, and assuring adequate flexibility to meet future conditions through a board of appeals or adjustment and by amendment of the zoning ordinance.

(Legal machinery for the adoption of zoning covering the expansion area by the central cities is lacking in most states. In Indiana, cities are exercising this function, and in Kentucky the fiscal courts of the counties may adopt zoning in cooperation with the city involved. In some states counties or townships may enact zoning ordinances covering expansion areas. Where there is no legal authority for the official adoption of zoning in the expansion area, planning commissions may prepare land-use plans to serve as guides and through persuasion and the utilization of subdivision control may go far toward attainment of the land-use objective.)

2. The major thoroughfare plan designating the location and width of thoroughfares, existing and proposed, throughout the expansion area.

3. The neighborhood development plan showing designs for neighborhoods in the expansion area, appropriate to the terrain, and illustrating the application of sound principles of design.

4. Regulations setting up standards for the design of subdivisions and their elements and providing for the submission of preliminary and final plans for approval of the planning authority before plats may be recorded.

(Most, if not all states delegate this authority to city plan commissions, extending varying distances beyond the city limits. This procedure assists the planning authority in convincing owners and developers of land of the multiple benefits which may be derived from following the sound principles set forth in the master plan.)

The success of technical guidance by city planners in directing the expansion of cities depends on the quality of the master plan, on thorough understanding of the value of the plan by the public, property owners, and developers, and on the ability and everlasting courage of the planning authority in administering the guiding plan in accordance with the sound principles which it portrays.

(This article has been prepared from the paper presented by Mr. Sheridan before the City Planning Division session presided over by H. W. Alexander, chairman of the Division's Executive Committee, at the Centennial Convention in Chicago.)

This discussion of the larger implications of irrigation development is a digest of part of the longer paper by the author, "The Planning of an Irrigation Project in the United States Today." It brings into focus the place of irrigation in the United States, and its relation to the world, together with the differences in philosophy of the federal laws, and the conclusions contained in the recent report on "National Water Policy" by the Water Policy Panel of the Engineers Joint Council. The complete paper, including the technical and documentary portions, is available as Centennial Convention Preprint No. 58. This paper was presented before the Irrigation and Drainage Division, with George S. Knapp, a member of the Division's Executive Committee, presiding.

J. W. DIXON, M. ASCE

Director of Project Planning

U.S. Bureau of Reclamation

Washington, D.C.

Social and economic implications of irrigation development

To be most constructive in approaching this subject of the social and economic implications of irrigation development, it is necessary to start with the engineer himself, the man who is responsible for preparing project plans. At the annual dinner of the District of Columbia Section, Carlton S. Proctor, President of the ASCE, stated the problem squarely when he said: "In a situation in which we [the engineers] have been the prime movers we have passed the solution [to the social and economic problems] on to the social scientists, the lawyers, and the clergy, while the politicians have been quick to exploit our ineptitude." Dr. Alberto Lleras, Secretary General of the Organization of American States (more popularly, if erroneously, referred to as the Pan American Union), also very deftly touched on the responsibility of engineers to bring about a homogeneous economic status in the nations of the Western Hemisphere.

President Proctor quoted a recent *Engineering Societies News Letter* which hits a practical and vital note when it says:

> Engineering works are not applied in a vacuum, but in a political climate, and they have practically revolutionized society. The engineering profession is certain of its future technologically, but society is by no means certain of its future politically. The next few years will undoubtedly see the engineering profession placing less stress on its technical abilities, and turning more and more toward a concerted program of techno-political activities.

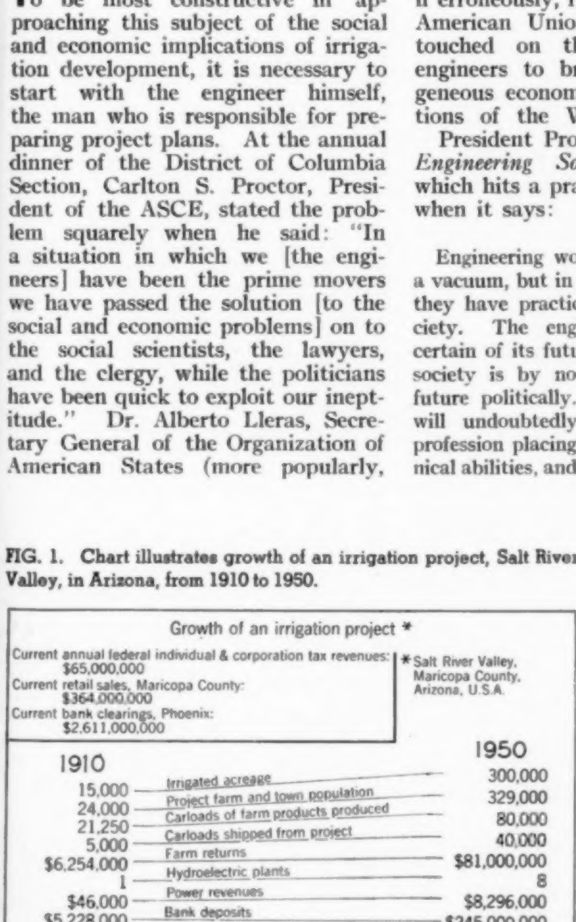
Technologically, we in the United States have been sound and aggressive, but most of us are immature in our concept of techno-political activities. We are inclined to forget that our projects not only are for the development of the resources of the nation, but also are inevitably a part of the world-wide irrigation development which has a significant relation to the economic and social peace of the world.

Our responsibility in the Bureau of Reclamation is a peculiar one in that our basic responsibility is for irrigation development in the United States and its possessions. A further responsibility, which has expanded recently, is to render technical assistance, under the United Nations and the State Department and others, to many nations throughout the world.

We think of irrigation in the United States as being limited to the West but it is not; it is practiced in varying degrees in every state of the Union. While the West has the larger area of irrigated lands, the proportionate growth of such areas in the East in the last ten years has been five times as fast as in the West.

Since the inception of federal irrigation in the United States on a broad scale some fifty years ago, our concept of an adequate plan has changed as our experience and comprehension of how to utilize our

FIG. 1. Chart illustrates growth of an irrigation project, Salt River Valley, in Arizona, from 1910 to 1950.



opportunities have grown. Starting off usually with single-purpose projects, we have added hydroelectric development, then storage to control, conserve, and utilize flood waters, and facilities for numerous other purposes. In the past two decades we would have been considered remiss had we not taken into account all possible services in preparing the plans for any project. In essence, that is the multiple-purpose project—to create the greatest total benefits at minimum cost, and with minimum conflict among the services to be rendered.

The planning for a major irrigation project cannot be, and should not be disassociated from the planning for the development of other natural and economic resources, including the opportunities that may be created for commerce and industry.

When this fact is fully assimilated on a world-wide scale, and when the real need for food throughout the world becomes something that the whole world is working on and not just talking about, the reclamation engineer will, in truth, become a tool toward world peace.

We have also learned in the United States how irrigation development can lead to an expanding economy by creating new wealth in the form of food, clothing, the products of industry, and the basic stability which comes from economic well-being.

But it must not be presumed that a wise water development program can be undertaken in foolhardy haste, for it is always necessary first to have adequate basic data.

The purposes that can be served will vary from project to project, in terms of both need in the project area, and the capability of the project to render the desired services.

Of the many purposes that may be served, nine are most common: irrigation, flood control, hydroelectric power, municipal and industrial water supplies, navigation, public health, fish and wildlife, recreation, and drainage. Each of these is discussed in more detail in the full paper, but I should like to touch briefly on the place of irrigation.

Irrigation

Thirty years ago, the United States changed from a nation with a net export of foodstuffs to one with a net import of foodstuffs. We have no more land under cultivation today than we had in 1920. Yet we are feeding 45 million more people, and they are being fed on a higher standard of living.

Many factors help make this possible. One intrigues me, namely, that through the rapid growth in the use of automobiles, tractors, and trucks the number of horses has been so reduced that 60 million acres of land formerly used to grow hay and fodder are now used for the production of food for humans.

The place of irrigation throughout the world has even more significance. About six-tenths of one percent of the world's land area is irrigated, yet it supports about 25 percent of the world's population.

Each year the world population increases about 20,000,000 people; simply stated, each day the world has 70,000 more people to feed than it had the preceding day. Yet, in the last ten years there has been a 3 percent decrease in the cultivated area of the world. As Sir John Orr, the first President of the United Nations Food and Agriculture Organization, said, "In the race between population and food, population is winning." Our plans in the United States must therefore contemplate a population increase of at least 40,000,000 people within the next 25 years.

The United States has the fourth largest program of irrigation development of any nation in the world, being exceeded by India, Pakistan, and China. Many other countries have substantial areas, and some nations are wholly dependent on irrigation for agricultural purposes. Probably nowhere in the world is it more apparent that food is essential for survival than in the southern Asiatic countries, an area of new governments and an awakening people. Happily, those countries are blessed with rich, undeveloped natural resources, and much can be done to remedy the situation.

A recent survey conducted by our Bureau dealt with the national policies of the countries of the world for financing irrigation projects. Most governments assist in one degree or another. Nations that have practiced irrigation over the longest periods of time are the ones that generally provide the greatest degree of federal participation. Those which are younger, in terms of irrigation practice as a national undertaking, generally require a high degree of individual financial participation by the immediate beneficiaries. The United States is such a nation.

Yet, an examination of 15 federal reclamation projects that collectively cost \$285 million, shows that to date the federal government has collected some \$525 million in individual income taxes from those same areas. Other federal taxes, such as corporation income taxes and excise taxes, have produced an additional \$250 million. This \$775 million of federal income is over and beyond any direct repayment by immediate beneficiaries, and this tax income will continue to come in annually.

To illustrate more specifically the economic results of the federal reclamation policy in the United States, the chart, Fig. 1, based on the Salt River Project of Arizona, is presented.

Multiple-Purpose and Basin-Wide Plans

When the multiple-purpose concept becomes a clear and workable tool to the engineer, it automatically takes him at least two further steps.

The first step is the recognition of the relationship of all projects within a given river basin, each to the other. As the water resources of any given river basin are more and more fully utilized, it is essential to approach the planning job on a basin-wide basis, for new projects must complement, and not interfere with, existing developments. And new projects must not prevent ultimate full development by usurping sites that would be economic for large projects and devoting them to lesser uses.

The next inevitable step is the interbasin or regional plan. Water can be and is being exported from one river basin to another. So is electric energy for use outside the basin of origin. Nor are mineral deposits, timber growths, or the lines of commerce limited to use in a particular basin.

Leadership is needed within each country so that its particular needs can best be met according to its own devices and yardsticks. And continued leadership and even greater effort is needed among the nations for the solution of controversies, and for the preparation of plans to utilize such international streams as the Danube, the Nile, the Rio Grande, the St. Lawrence, the Columbia, the Indus and many others.

Philosophy of Federal Development in the United States

The composition of a plan, its purposes, and the peoples which it serves dictate many controlling principles on which it must be predicated. There are, nevertheless, other controlling principles, namely, those laid down as basic policy within each nation to guide its own procedures.

A federal irrigation or multiple-

(Continued on page 250)

L. N. McCLELLAN, M. ASCE

Chief Engineer, Bureau of Reclamation, Denver, Colo.

Progress in irrigation engineering

Irrigation *practice* is as old as civilization itself. Early civilizations in arid areas depended on irrigation and flourished where canals brought water from nearby streams to sustain plant life and assure crop yields.

Irrigation *engineering* is of comparatively recent origin. Its progress has been rapid, particularly during the last 100 years when the settlement and development of our western states were made possible through irrigation enterprise.

Since the enactment of the Reclamation Act 50 years ago, on June 17, 1902, the construction of irrigation works by the Federal Government has brought water to more than 5 million acres of western land. This acreage is exceeded four times by private irrigation developments in the United States and many times over by irrigated areas in other countries. However, its development has been a potent influence on the welfare and stability of a large section of the West.

From an engineering standpoint, the accomplishments of the Bureau of Reclamation in the design and construction of structures for irrigation—and in the development of associated hydroelectric power—have contributed a substantial volume and diversity of experience to irrigation practice. They have also assisted in the evolution of reclamation policy and economic principles.

Design Answers Irrigation Needs

The ever-increasing demand for irrigation has been a vital force in the advancement of irrigation engineering. The need for closer conservation has impelled successive progress in design as demands on scant western water supplies have become stronger. Changes in the basic concepts of irrigation projects fostered new engineering designs. The evolution of the relatively simple irrigation project into the multiple-purpose development and, more recently, the coordinated development of river basins, have presented new challenges in the design phase of irrigation engineering.

Rapid construction progress during the first 5 years of reclamation activity was made possible by the adaptation of construction equipment and skills developed during the era of large-scale railroad construction from 1880 to 1900. To a considerable extent, improvements in design during this period and later years accompanied the development of construction equipment, particularly excavating machinery.

The early formative period encouraged many modifications in design as work progressed. As later irrigation projects embraced structures of increasing size and complexity, flexibility of design methods and reliance on empirical procedures gave way to more thorough study of site and materials and to more complete designs before the start of construction.

Early irrigation undertakings in the West depended for the most part on use of unregulated stream flows brought to the land by ditches headed at small diversion dams. These unregulated flows, however, were not sufficient for irrigation needs, and dams of increased height and volume were required to store and regulate water.

A basic contribution to the design of dams has been the improvement of hydrologic techniques in forecasting stream runoff, which have enabled the designer to provide economical spillways of adequate capacity to safely pass reservoir overflows from floods. The adoption of the unit hydrograph in 1932, and subsequent refinements in computing and analyzing runoff from rainfall and snow melt, have aided greatly in planning and designing dams and reservoirs.

Experience in the development of early concrete and masonry dams, such as Buffalo Bill (Wyoming), Roosevelt (Arizona), Pathfinder (Wyoming), Arrowrock (Idaho), and Elephant Butte (New Mexico), led the way to the design of dams with heights and volumes previously considered impossible to attain. Advances followed in the design of multiple-arch dams, reinforced-concrete slab and buttress dams, and other special types of concrete dams.

The principle of trial-load analysis, which was evolved during the 1920's for the first time took into account the interaction of horizontal beam or arch action with vertical cantilever action in the structure in determining the economic safety factor. Its first important application was in the design of Hoover Dam (Arizona-Nevada).

New procedures were worked out to control the temperature of the concrete placed in Hoover Dam. The potentially high temperature developed in the mass concrete of the 726-ft-high dam was counteracted by the use of low-heat cements and by an embedded pipe cooling system through which river water and refrigerated water were circulated to remove the excess heat resulting from cement hydration. To localize shrinkage and to minimize random cracking, Hoover Dam and later massive dams were built in vertical blocks separated by contraction joints which were grouted to make the

structures monoliths after temperatures became stable.

With the establishment of the Bureau's engineering laboratories in the early 1930's, hydraulic models were used extensively to confirm designs for spillways and outlet works for dams. Experience demonstrated that hydraulic models provided a reliable means of ascertaining and alleviating undesirable conditions such as subatmospheric pressures on water-passage surfaces and the choking of shaft spillways.

During the 1930's, procedures were developed for grouting dam foundations to improve their watertightness and stability and to reduce uplift pressures under concrete dams. Grouting techniques were improved by more accurate determination of spacing, location, and depth of drill holes, and by close control of grout mixtures and pressures for varying conditions.

Much progress has been made in the design and construction of earth dams. Many of the early earth dams were designed with little attempt at analysis of structural behavior. They were built with only elementary selection of materials and control of moisture and compaction. However, the experience derived from their construction, and advances in soil mechanics, led to the adoption of definite principles and construction control.

Compacted earth-fill dams have been accepted for wide use and they are now economically designed with the same assurances of safety and permanence as are other types of dams. In the transition of earth dam design from about 1925 to the present time, important advances have been made in basic soil mechanics and in design techniques. Methods of analyzing the stability of earth embankments were developed. Data obtained from settlement and internal-pressure measurements, conducted at most major earth dams since 1935, and the criteria evolved for moisture control, material selection, and embankment placement have both contributed substantially to the advancement of earth dam design and construction.

The design of hydraulic equipment to control the release of water from dams has paralleled progress in dam design. Problems of deterioration of valves and gates by cavitation and corrosion have been lessened through better hydraulic and mechanical design and the development of more resistant materials. The increasing demand for larger gates and valves to operate under higher heads has led to progressive improvement in operating gates, emergency gates, and regulating valves.

Butterfly valves or sliding leaf gates have been developed for emergency closure of penstocks and outlet pipes. To adapt the sliding leaf gate to the higher heads, ring followers and wheels were added to withstand the high thrust and reduce the friction. Gates of this type have been designed for 120-in. conduits and for heads of more than 600 ft.

One of the earliest regulating valves was of the cylinder type. Higher heads required improved designs which were represented first by a needle-type valve. Several major changes resulted in the interior differential needle valve, followed by the tube valve, and finally the present hollow-jet valve. Sizes have been built up to 108 in. in diameter and for heads in excess of 460 ft.

Since 1902, approximately 20,000 miles of canals and more than 200,000 related irrigation structures on reclamation projects have been designed and constructed. The canals, lined and unlined, range in capacity from a few cubic feet per second up to 16,000 cfs.

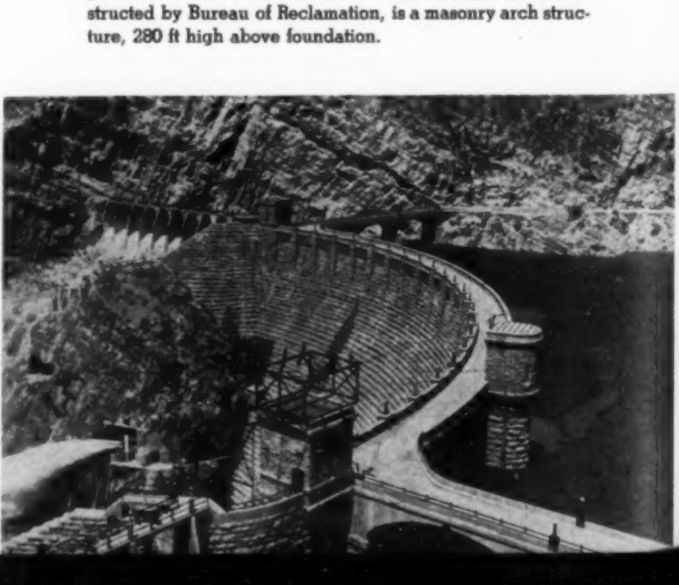
The design of large canals and of smaller conveyance and distribution structures has been directed toward one basic objective—to deliver water in adequate quantity from the source of supply to the point of use efficiently and at minimum cost. Over the past 50 years refinements in hydraulic theory and soil mechanics procedures, the development of canal linings, and improvements in construction equipment and controls have aided in reaching this engineering goal. The techniques developed for underdrainage of linings and stabilization of canal banks, and improvements in weed control and other maintenance procedures, have also made possible greater efficiency and economies in water distribution.

Prior to the start of reclamation construction in the West, little consideration was given to the establishment of canal standards. An initial undertaking was the development of hydraulic and earthwork standards for trapezoidal canal sections. These early compilations were progressively improved, and are now widely accepted as standards in the design of hydraulic channels.

In the years that followed, emphasis was given to lowering costs of canal construction and to improving canal alignments, particularly those of main supply arteries. This endeavor was given further impetus by initiation of a lower-cost canal lining program in 1946. Research and investigation of materials and methods in field, laboratory, and design offices have reduced the costs of lining many canals. Concrete linings and pneumatically-placed mortar linings have been improved. A far-reaching development is the elimination of steel reinforcement in concrete canal linings except under certain conditions—thus making possible a saving of 10 to 15 percent in the total cost of the linings.

Two general types of asphaltic canal linings have been developed and are being used successfully—buried asphalt membrane and asphaltic concrete. The newly-developed buried membrane consists of a thin layer of asphalt sprayed in place at high temperature and covered with a protective layer of earth materials.

Roosevelt Dam on Salt River project in Arizona was completed in 1911. This dam, one of earliest major dams constructed by Bureau of Reclamation, is a masonry arch structure, 280 ft high above foundation.



Earth linings have proved economical. The heavy-type compacted earth lining is particularly effective as a low-cost lining for medium-size and large-size canals. This lining, about 3 ft thick, is inexpensive to place where suitable materials are available, requires little protection from erosion, and is about as impervious as concrete lining.

Developments in the design and manufacture of concrete pipe have made possible its wider use for distribution systems and canal structures. The early pipe, cast in small sizes by hand-tamping mortar into forms, has been replaced by mass-produced concrete pipe with diameters up to 9 ft, and in special cases up to 15 ft. Operation of reinforced-concrete pipe under progressively higher heads accompanied the introduction of metal joints and later of rubber-gasket joints.

In addition to these important design advances, the past 50 years have been characterized by progress in the design of diversion dams, large wasteways, detention dikes, high-head pipelines, and appurtenant canal features such as checks, drops, and turnouts. Inverted siphons constructed of concrete pipe or cast-in-place concrete have largely replaced the timber-trestled flumes of early designs. Automatic controls for checks and wasteways and devices for measuring flows in large canals have been found useful in the operation of modern irrigation systems.

Operation and Maintenance Stressed

Dams, reservoirs, and distribution systems on reclamation projects must be properly operated and maintained if the investment in irrigation and related work and the welfare and interests of the citizens on reclamation projects are to be protected. During early reclamation activity little consideration was given to the proper techniques of water application and land management. In later years more attention was given to the requirements of the crops and to the water-holding capacity of the soil, and still greater attention was directed toward decreasing losses of both water and soil on the farm.

There has been a significant trend in recent years toward mechanization of irrigation project operation. Two-way radio communication systems have been installed, and maintenance personnel can communicate directly with the operating office. Through remote-control systems, operators at central locations can control the operation of gates or other works many miles away by electrical circuits. Automatic equipment in pumping plants has made possible the unattended operation of such facilities.

Through research in the chemical laboratories, new economical methods have been developed to control aquatic weeds. Aromatic solvents such as cheap coal-tar naphtha have been found to be more effective in killing aquatic weeds than previous expensive hand or mechanical methods.

In the early years of reclamation development, inadequate consideration was given to surface and subsurface drainage. The importance of preventing the destruction of valuable land by waterlogging, salts, and alkalis was not recognized.

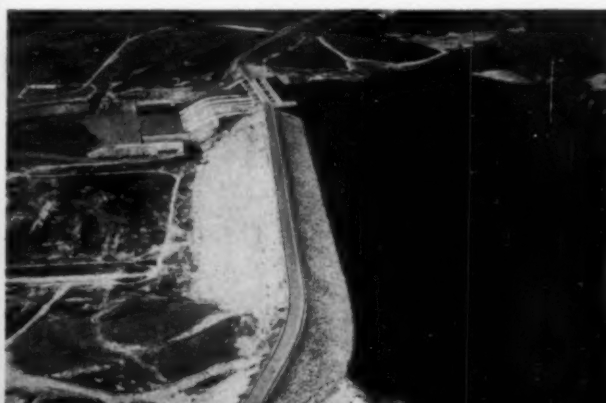
To maintain the productivity of irrigated lands, investigations were begun in 1911 to determine the elevation of ground waters, and the construction of necessary drainage facilities was undertaken. Through increased knowledge in recent years of the physical and chemical characteristics of soils and of the factors affecting ground-water movement, it has been possible to construct efficient drains, wells, and other drainage relief devices as integral parts of irrigation projects. After projects are constructed, the productive capacity of the land is maintained through continuing drainage studies and activities.

Construction Art Advances

During the past 50 years, a tremendous advance in the construction art has taken place. Great improvements were made in internal-combustion engines and self-propelled machinery. In particular, the development of equipment for the excavation, conveyance, and placement of materials was outstanding. New and improved machines, because of their greater capacity, durability, and speed of performance, made possible the accomplishment of work on a scope and a volume that otherwise might have been economically infeasible. On reclamation projects the magnitude of the work undertaken closely paralleled the development of equipment and the allied improvements in construction plants and methods. Progress in construction through the development of new equipment and methods is strikingly demonstrated by comparison of early methods with modern practices.

At the time reclamation construction in the West began, the horse-drawn drag scraper—slip or fresno—

Enders Dam in Nebraska is one of twelve reclamation dams that have been constructed on Missouri River Basin project. Construction of large earth dams such as Enders has been made possible by important advances in soil mechanics and design techniques during past 25 years.



Davis Dam, recently completed on Colorado River, reregulates water releases from Hoover Dam for irrigation and power development and for other purposes including delivery of water to Mexico. In foreground are spillway and power plant. Part of earth-fill embankment is visible at left.

was the principal implement used in the excavation of canals, although steam shovels were used as early as 1903 on canal construction on the Newlands project in Nevada. The moving of excavated materials, until about 1910, was done principally by horse-drawn wheeled scrapers and one-yard wagons.

By 1915, the transition from horse power to gasoline power was well under way, and by 1920 the gasoline engine and the steam engine had been so developed for heavy construction purposes that they almost entirely replaced the horse and mule. About 1930, draglines of large capacity were developed. Some of these machines, rated at 18-cu yd capacity, were used in 1934 for construction of the 80-mile All-American Canal in California.

The development of internal-combustion engines and electric power had a similar effect on concrete canal lining and on excavation. The first canal lining machine was used on the Umatilla project in Oregon in 1914. This machine, like the others that followed later on other projects, traveled on rails at the top of each canal bank, finishing the concrete lining over the entire canal perimeter as it moved along the canal. In recent years, these large machines have lined canals of more than 100-ft width on the Columbia Basin (Washington) and Central Valley (California) projects.

Advances in construction of concrete dams, particularly in the last 25 years, have been made possible by greatly improved techniques of concrete manufacture and methods of transportation and placement. Beginning with the construction of Hoover Dam in 1931, accurate batching and mixing plants have been used to assure automatically predetermined proportions of aggregate, cement, and water, and consistent uniformity of mix.

At Grand Coulee Dam, on the Columbia Basin project, which contains 10,585,000 cu yd of concrete, the aggregate processing plant had a rated capacity of 3,000 to 4,000 tons per hour and was designed to wash, screen, and store separately four sizes of gravel and three sizes of sand. Concrete was delivered to the dam at the average rate of 1 cu yd every 5 sec. At one time, the rate of placement of concrete reached 20,600 cu yd during a 24-hour period.

Despite the short season at Hungry Horse Dam (now under construction in Montana) more than 2,000,000 cu yd of the 3,000,000-cu yd structure were placed in 17 working months. In August 1951 alone, more than 227,000 cu yd of concrete were placed in the dam.

Since 1925, embankment control for rolled earth dams involving close supervision of excavation, placing, and compaction of the materials has become a recognized procedure.

Earth moving and placing equipment, including large elevating graders, tractor-drawn scrapers holding 30 or more cubic yards of material, fast-moving bottom-dump wagons of equally large capacity, and sheepsfoot rollers have made possible great advances in earth-dam construction. Comparison of the rates of progress in building the Belle Fourche Dam (1906–1910) on the Belle Fourche project in South Dakota and the construction of Bonny Dam (1948–1951) on the Missouri River Basin project in Colorado is interesting. In the working season of 1909 at the Belle Fourche Dam, 529,000 cu yd were placed in the dam in about 7 months. At Bonny Dam, which was completed a year and a half ahead of schedule, more than 1,000,000 cu yd were placed during the maximum month of November 1949.

Work Done on Contract Basis

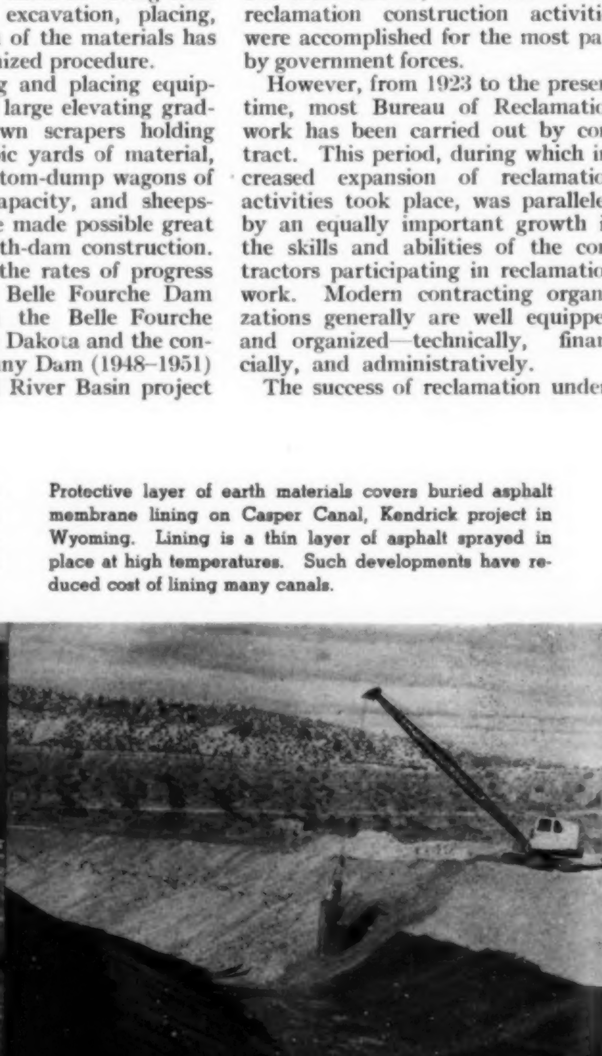
The Reclamation Act of 1902 gave the Secretary of the Interior authority to let contracts for constructing principal works on reclamation projects. Difficulties were encountered early in contract work because many contractors were inexperienced in such undertakings and were unprepared to assume the financial responsibility required to complete government contracts.

Because of these difficulties and ensuing problems in obtaining suitable labor during the period of great expansion of construction in the West, beginning about 1905, contracts became increasingly difficult to fulfill. For these reasons, from 1911 to 1923 reclamation construction activities were accomplished for the most part by government forces.

However, from 1923 to the present time, most Bureau of Reclamation work has been carried out by contract. This period, during which increased expansion of reclamation activities took place, was paralleled by an equally important growth in the skills and abilities of the contractors participating in reclamation work. Modern contracting organizations generally are well equipped and organized—technically, financially, and administratively.

The success of reclamation under-

Friant-Kern Canal on the Central Valley project in California, shown here in its initial reach downstream from Friant Dam, is major artery of project's irrigation development. Most of concrete lining is unreinforced. Initial capacity of 155-mile-long canal is 5,000 cfs.



Protective layer of earth materials covers buried asphalt membrane lining on Casper Canal, Kendrick project in Wyoming. Lining is a thin layer of asphalt sprayed in place at high temperatures. Such developments have reduced cost of lining many canals.

takings may be credited in large part to the ingenuity, capacity, and resourcefulness of the contracting industry. In recent years, the contractual relationships between the Bureau and contractors have been strengthened by periodic conferences and mutual study of problems. This cooperation has been reflected in reduction of construction costs and improved quality of performance.

Projects Become Multiple Purpose

The first reclamation projects were constructed for a single purpose—to provide irrigation. But early in the experience of the Bureau, power became an important adjunct to irrigation. The first hydroelectric power installation on a reclamation project was a small temporary plant on the Salt River Valley project in Arizona, built in 1906 to supply electric power for the construction of Roosevelt Dam.

Passage of the Boulder Canyon Project Act in 1928 signified a marked advance in the concept of water conservation and in the importance of hydroelectric power development for reclamation projects. This act embodied for the first time the concept of multiple-purpose development of water resources. The Boulder Canyon project comprises Hoover Dam and power plant, Imperial Dam and desilting works, and the All-American Canal system. Sale of the power generated will repay 90 percent of the cost of the project, with interest.

The Reclamation Project Act of 1939 increased the maximum period of power leases from 10 to 40 years, and authorized rates that would recover not only the costs allocated to power but also an appropriate share of the construction costs allocated to irrigation where such costs were in excess of the water users' ability to pay.

Early pumping plants were built on several reclamation projects, among them the Huntley project in Montana and the Minidoka project in Idaho. These plants pumped water to lands too high to be served by the gravity systems.

As the possibilities of pumping methods in certain areas became increasingly apparent, and were enhanced by the development of hydroelectric power, additional pumping plants were constructed and placed in operation. Heights of pumping lifts increased with the improvement of pump efficiency, and the feasibility of pumping for irrigation likewise increased.

In the summer of 1951, a new era in pumping for irrigation began. Three of the world's largest pumping plants were placed in initial operation. Largest of these is the Grand Coulee pumping plant on the Columbia Basin project. This plant will house 12 pumping units, each capable of delivering 1,350 cfs of water at a rated head of 310 ft. Each pump is driven by an electric motor of 65,000 hp. Four of the pumping units are completed and will be utilized during the irrigation season of 1952 to pump water for delivery to 66,000 acres of land—the first irrigation block of the huge project.

The second largest pumping installation is the Tracy pumping plant on the Central Valley project. The plant is the prime mover in the transfer of surplus water from the Sacramento River to lands in the San Joaquin Valley. The installation consists of six units, each rated at a capacity of 767 cfs at a head of 197 ft.

Another recently constructed plant is the Granby pumping plant on the Colorado–Big Thompson project in Colorado. The Granby pumping plant lifts water to the western portal of the Adams Tunnel, which carries the water from the western slope of the Rocky Mountains through the Continental Divide to the eastern slope. The plant houses three pumps, each rated at a capacity of 200 cfs at the maximum pumping head of 186 ft.

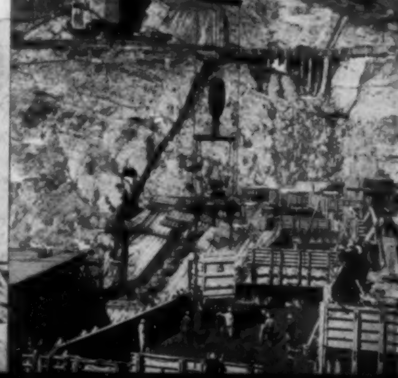
Future Brings New Challenges

Irrigation engineering in the future faces challenging problems. Water for new irrigation projects must be transported greater distances, which will bring new problems of storage, pumping, and conveyance. The exchange of water through multiple-basin exportation systems may be necessary before full utilization of western water resources can be realized. Other complex and diversified problems in the development of domestic water supplies, flood control, and control of silt will be imposed on future reclamation undertakings. The experience gained in irrigation engineering during the last 50 years will be of immeasurable value in the development of the more difficult and complex irrigation projects of the future.

The photographs accompanying this article are used by courtesy of the Bureau of Reclamation.

(This article is based on the paper presented by Mr. McClellan before the Irrigation and Drainage Division, presided over by W. E. Blomgren, M. ASCE, at the Centennial Convention in Chicago.)

Left: Recently developed heavy-type compacted earth lining used on this section of Friant-Kern Canal is particularly effective as low-cost lining for medium-size and large-size canals where suitable soils are available. Right: Large-scale concrete manufacturing and placement systems have made possible rapid building of large concrete dams such as Hungry Horse Dam, now under construction in Montana. Despite short working season, more than 2,000,000 cu yd of 3,000,000-cu yd structure were placed in 17 working months. Placement of concrete in dam will be completed in 1952.



S. T. HARDING, M. ASCE

Consulting Engineer, Berkeley, Calif.

Water Law in the United States

With particular reference to the Western States

The Centennial of Engineering, of which this meeting of the Irrigation and Drainage Division is a part, covers the period of time during which the present water law in the United States has been developed. Title to the use of water becomes important only when the demand exceeds the available supply. A hundred years ago there were many uses of water but the amount of use had not resulted in such deficiencies that complete definition of the basis of title to use was required.

In the humid eastern states the early settlers, coming principally from England and finding conditions generally similar to those in the area from which they came, naturally transplanted the English common law of waters to their new homes. This law, which gave riparian rights on surface streams and complete title to underlying ground waters to the landowner, met such needs as arose in the settlement of these humid areas.

Water had been used for irrigation for what was then a relatively long time in some southwestern areas in the United States under practices brought in by the Spaniards. Not until extensive use of water for mining began in the western states just about 100 years ago did the need arise for the development of a system of title to the water in surface streams which was adapted to the arid conditions in the western states. The customs developed by the early western miners became the principles of the system of appropriation rights now so thoroughly established in the arid areas of the United States.

Over the past 100 years each of these two basic principles of water law have been subjected to the modifications needed to meet the requirements of a country progressing from pioneering conditions to a stable economy. Further changes are occurring and will continue to be necessary to keep water law abreast of expanding development.

Under our system of government we do not have what can be called a national system of water law. Each state may adopt the system which it considers best. With the wide diversity in climatic conditions in the different states this is a major advantage in securing systems of water law suited to local conditions. The general system of riparian rights has been found to be well adapted to humid areas. Similarly the appropriation doctrine has been found to be preferable for conditions in arid areas. However, it is difficult to select and apply an appropriate system of title in the semi-arid states. In some states variations have been used within the state in order to meet more nearly the climatic conditions of the different parts.

Water law is a technical subject having many finely-drawn distinctions. This article will not attempt to examine the more technical features, but rather will present a general survey of present practices with a discussion of the development and changes which may occur in the future.

No excuse is needed when an engineer undertakes to discuss a legal subject such as water law. The greater part of the procedure involving rights to the use of water relates

Needs in the Field of Water Law

There is a growing need for more complete definition of rights to water under the many variable conditions of its use. This need is the natural result of greater use of our water resources. More exactness is essential both in the principles and in their applications.

Any problems can and should be solved without major modifications in the present basic concepts of water law. Future changes should amplify and refine rather than fundamentally revise. Relatively speaking, such advances are more necessary for ground-water supplies than for surface streams.

to factual matters. The administration of water law is mainly under the direction of engineers, who require a knowledge of the controlling legal principles although their work is concerned mainly with the application of such principles to the widely varying physical conditions of water supply. Engineers in this field should be and are qualified to discuss the general policies of water law.

The physical conditions under which surface and underground waters are produced differ so materially that separate systems of title are needed. The flow in surface streams must be used as it occurs or it will be lost. The water may be conserved by diversion of direct flow or by storage, but the actual surface flow leaving the stream system is lost. Ground water is itself a form of storage and permits much more flexibility in the time and rate of its use. Surface waters are accessible for measurement and can be divided readily among legitimate consumers. Ground waters are difficult to administer quantitatively as measurement generally has to be made by some form of indirect determination. The development of water law can be discussed more conveniently by treating these two classes of water supply separately.

Surface Waters

As previously mentioned, the older of the two systems of title to the use of water prevalent in the United States is known as the riparian rights doctrine, which was transplanted from England. In England water was needed for domestic and stock use and the generation of power at mill sites. Thus there was developed a recognition of advantage of position in securing water, and the riparian owners along a stream were given the rights to its flow. Between different riparian owners, rights were generally relative, each being entitled to a reasonable share of the available supply. This system is generally well adapted to the humid eastern states where consumption is usually less than the available supply. Also, each riparian owner may develop the power within the section of the stream under his riparian ownership.

The appropriation system is the outgrowth of early mining practices in the West, which at that time was open public land without laws for acquirement by the miners. Thus the miners made their own rules for both land and water titles. Among the miners, priority of possession, continuation of operation, and limitation on the area which could be acquired were the basic rules of title to mineral claims. These rules were matched in the title to the use of water for the mining claims by priority of appropriation, diligence in construction and use, and the restriction of the amount withdrawn to the reasonable needs. Although there were similar practices in other areas, the development of this system among the miners was largely spontaneous and original. These principles remain today as the main basis for the appropriation system of water rights.

For arid areas the appropriation system has demonstrated its adaptability to the conditions. Priority of right to the one first in time would be capable of abuse if the prior right were not limited by the requirement of diligence in completing actual use and if the extent of the right were not in turn limited to the amounts needed under reasonable standards of beneficial use.

The appropriation system is now established as the exclusive system in the more arid western states. In the three Pacific Coast States, early recognition of riparian rights has been overcome by restrictions on their application, so that in Oregon and Washington nearly all rights are now practically on an appropriation basis. California went further in recognizing riparian rights and took longer to work out a basis for their limitation. In California reasonable use is still recognized for riparian lands on a riparian-right basis but the former unreasonable advantage of riparian lands over non-riparian areas is no longer in effect. In the semiarid states of the Great Plains, conflicts between the riparian and appropriation systems have not been extensive. Large projects based on storage are proceeding without essential distinction between riparian and non-riparian lands.

Acquirement of New Rights

Under the riparian system, water rights are inherent in the land and no separate procedure is required to secure rights to the use of water. Under the appropriation system, title to the use of water is obtained under a procedure which is separate from the acquirement of title to the land on which the water is to be used.

The procedure for the acquisition of appropriation rights has developed over the last 100 years from a simple declaration of intention to a state-supervised form of application, permit, and license. This change is the natural result of the need for a more definite, readily available, and up-to-date record of the status of rights during their period of acquirement. The early users were only required to post a notice of intention at their proposed point of diversion and to record a copy of the notice with the county.

No further steps were necessary to record which notices had been followed by actual construction and there was no limit on the amount of water which could be claimed. At present nearly all western states require that an application to appropriate water be made to some state agency. The degree of discretionary control over the granting of such applications differs widely among the individual states. In Colorado the application is still only a declaration of intention with control by the state limited to the content and form of the application. In several other states, the state agency has varying degrees of authority to reject applications. Grounds for rejection may be inadequacy in the application itself, absence of unappropriated water in the source sought to be appropriated, lack of financial resources to carry out the project, or such a generality as not being in the public interest.

The western states have generally been averse to granting extensive discretionary powers to administrative officials to reject applications for appropriating the waters of the state. This policy in the early years was the result of fear that favoritism might be used and monopolies in water rights created. Some states still provide in their constitutions that the right to appropriate water shall not be denied. In such states, regulation is limited to requirements regarding the form and content of applications to appropriate.

As water supplies have been more fully used, support has developed for state guidance in apportioning the remaining unappropriated water so that it not only may be used beneficially but also may best serve the needs of the state. This policy has resulted in preferences between different classes of use and methods whereby the state could itself appropriate the remaining unused waters for state-selected and state-controlled projects.

In regard to preferments, domestic use, which now includes stock watering, is always rated first. Municipal use receives the same priority as domestic use although municipal

use includes industrial uses. Second preference is generally given to irrigation in the western states. Power and mining usually rank third.

Such preferences apply only to unappropriated water. When title has once become vested, a preferred use has no authority to take water from an inferior use except by proper condemnation procedure. When applications to appropriate the same water supply may be pending at the same time, preferences between classes of use can be used to select the applicant to receive the permit.

State withdrawal of unappropriated water or direct appropriation by the state is authorized in some states. Withdrawal can be used to withhold acquirement until plans offering the greatest public benefit can be worked out. Also, by direct appropriation the state can retain control of unappropriated water until a project considered to be best adapted for the maximum benefit can be planned and undertaken. Such state appropriations do not require state construction, as priority can be waived for projects meeting the state's program.

Determination of Existing Rights

No western state adopted methods of acquirement of water rights through state procedure until after many rights had become vested through use. To secure a definition of all rights on any stream, some form of quiet title or adjudication procedure is required.

Early adjudications of water rights in the United States were left entirely to court action between the contending claimants. Whereas suits to quiet title to land are a recognized and useful procedure, title to the use of water does not lend itself to a similar action by individual claimants. Titles belonging to all water users on a stream are interrelated, and all claimants need to be brought into a single action if the results are to be effective. Thus, court procedures were established in which all claimants could be made parties in a single adjudication with the decision binding on all. The cumbersomeness of such factual determinations, when conducted under the restrictive rules of court practice, led, in turn, to the establishment of administrative forms of adjudication by state agencies having semi-judicial powers. In the latter case the administrative agency was authorized to secure its own record of facts by its own field investigations rather than being limited to the evidence presented by the contending parties. The administrative agency method reduces the conflict of testimony on factual items as the measurements of such an agency are generally accepted by the claimants. This procedure has been found to shorten the time and reduce the cost of adjudications. It is now in effect in some form in nearly all the western states.

As determination by administrative or semi-judicial state agencies touches closely the functions of the courts, conflicts in jurisdiction have to be avoided. Different procedures are used in various states. In Wyoming the decisions of the administrative agency are final unless appealed to the courts. In Oregon, the administrative decision is always reported to the court and becomes final only when approved by the court. These differences affect procedures rather than results. Several states have found it preferable to follow the Oregon procedure in order to avoid the constitutional questions that might be raised if the full powers of a lower court were given to the administrative office.

It is essential that when all the existing rights have been defined on a stream some procedure be available whereby later rights can be defined without involving adjudicated rights. This result is secured when application to a state agency is required, the processing of which includes granting a permit to proceed and issuing a license on completion of construction and use. The license then becomes the equivalent of a supplemental decree to the new right, which has a priority based on its time of initiation.

Administration of Water Rights

It is not enough to define the extent of the individual rights to the use of water from any stream. It is also necessary to provide procedure for the administration of the stream to assure that the owners of the rights receive the supply to which they are entitled at the time and in the amount of their needs.

The appropriation system lends itself to the definition and administration of water rights more readily than the riparian system. An essential element in the administration of any system of title to the use of water is the definition of each right so that the administrating agency is only required to administer and not to determine a changing status of the rights themselves. Individual riparian rights, being relative, change quantitatively with changes in the available water supply. Appropriation rights are separate individually and are served in the order of priority. In arid areas recognizing riparian rights, difficulties in administration have resulted in limitations on riparian use which represent an approach to placing the riparian users on an appropriation system.

On a stream having many users, where the supply at times may be insufficient for all needs, administration of daily diversions is essential for orderly use. The administrators are usually called water masters or water commissioners. They work under the direction of the court making the adjudication, where the court method is in force. They work as state employees where the administrative method has been followed. However, a court may use state employees as its water commissioners. As a water master does not have judicial powers and cannot define water rights, a definition of rights is required before a water master can function. The costs of administration are usually assessed against water users, with state participation in some states.

Interstate Streams

Under our system of government, each state has jurisdiction over the waters within its boundaries but no direct jurisdiction within any other state. Our state boundaries were not determined by drainage areas and there are many interstate streams. Obviously an upper state cannot be allowed to use its waters without regard to the rights of lower states. To meet such conditions the federal courts are available to determine conflicts in use between the states. Federal court adjudication has been found, like state court adjudication, to be time consuming and expensive with the resulting decision based on a technical application of legal principles that is not always most advantageous to the states involved. Federal courts have generally adopted the principle of equitable apportionment of the available supply between the states, leaving the detailed division of the share of any state among the users in that state to the state concerned.

A more direct procedure was found necessary for interstate streams as well as for streams within the states. This was found in the so-called interstate compacts. The federal constitution provides that states may enter into compacts covering matters of joint interest. These compacts are

subject to approval by Congress before they become effective. An interstate compact is, in effect, a treaty between the states. Interstate water compacts have been held to be binding and limiting on individual rights within a state.

The compact method has largely replaced federal court adjudication for interstate streams. This statement applies to the apportioning of water on interstate streams in arid areas and to eastern streams where the subject of the compact may be either pollution or other forms of stream use.

Both adjudication in federal courts and interstate compacts seem preferable to their alternative, which is complete federal control of interstate streams. Although no system of dividing an inadequate water supply among claimants to its use can be expected to work to the entire satisfaction of all concerned, the advantages of retaining local control in the states are considered to outweigh greatly any claimed benefits from a single federal jurisdiction over all streams. It is incumbent on the supporters of continued state control to insure effective operation if the establishment of federal control is to be prevented.

Present Conditions and Future Needs

On nearly all western streams, the extent of use has reached the point where the supply is less than the demand at least during parts of the year. This condition requires and has resulted in some form of definition of existing rights so that the streams can be administered so that each right can secure the use to which it is entitled. Such adjudications and administration of appropriation rights have become well established and stabilized in the states where need for them has arisen. Further changes can be expected to be related to improvement in details rather than in fundamental principles.

There are now many streams in the western states for which rights have been defined and service is effectively administered. These include the Snake River in Idaho and the South Platte River in Colorado where extensive storage facilities have been constructed with the resulting commingling of natural flow and storage releases in the river channels.

In surface waters, as use continues to approach the total supply, projects for water development will continue to depend on regulation of the variable stream flows by storage. Closer administration will be required to meet the problems of determining the waters available for storage and of commingling the released stored water with the natural flow. Since return flow will continue to increase, a more complete definition of the character of rights to its use will be necessary for the many conditions under which it may occur. Transfers of water from the drainage area of origin to more valuable locations are becoming more frequent. The definition of what preference, if any, is to be given to the areas of origin in securing the use of the remaining unappropriated waters, is an active issue in some states.

How can these problems be solved? Surface waters are now being administered efficiently where conditions of use require effective supervision. As the need arises on additional streams, the same problems can be met by the application of present practices. No basic changes appear to be called for in the fundamental principles of the appropriation system or in the general administrative methods now being applied. Further definition and application of the basic principles to the increasingly complex conditions of use will continue to be needed and can be readily provided.

At present several western states fail to recognize the importance of adequate administration of the water rights on their streams. Often the head of the state agency in charge of administration of water rights, usually an engineer, is not given continuation of tenure and compensation commensurate with the value of his work to the state and the responsibilities of his position. Improvements in these conditions are needed if the states are to meet their responsibilities in water matters.

Ground Water

The development of the systems of title to the use of ground water has paralleled that for surface supplies since both have resulted from customs in areas of earlier use. In the case of ground waters the early courts had difficulty visualizing the nature of the supply for which they were attempting to establish rights.

In England ground waters were regarded as a part of the property of the surface landowners similar to the soil or underlying rock. Under strict English common law there could be no injury to others by the use of ground water because any use was within the right of the overlying owner to the property under his land. This rule was transplanted to our eastern states.

With the increased use of ground water, conflicts necessarily arose. The courts were reluctant to depart from the certain and easily applied English rule into any new field where decisions would be required on factual matters then poorly understood. Just a little more than 100 years ago an eastern court (Roath v. Driscoll, 20 Conn. 533, 1850) stated, in discussing ground water:

> It rises to great heights and moves collaterally, by influences beyond our apprehension. These influences are so secret, changeable and uncontrollable, we cannot subject them to the regulations of law, nor build upon them a system of rules, as has been done with streams upon the surface.

In spite of the difficulties involved, the cases where inequity occurred from the application of the English rule gradually forced the courts to modify this rule. Variations include the adoption of the rule of malice under which an overlying owner may not take ground water from his land merely because of malice toward his neighbor. Also, excessive taking for commercial sale which injured others has been restricted in some states. These were merely the first steps that led to legal recognition that ground water moved underground and that extensive taking affected the supply on adjacent lands. Eventually the courts in several eastern states adopted the so-called American rule under which overlying owners have varying degrees of correlative rights in the common ground-water supply.

Extensive use of ground water in California beginning about 1900 resulted in the need for a definition of the principles applicable to the title to its use. A system of correlative rights was adopted under which development has proceeded at a rapid rate. The experience in California, and in other states with extensively developed ground-water supplies, has furnished a background on which the merits of the different systems of title to ground water can be tested.

In California all persons owning land over a ground-water supply have equal rights in securing an equitable part of the available supply. Except for conditions where adverse use may have ripened into a prescriptive right, priority among overlying owners is not recognized. If the ground-water supply exceeds the reasonable needs of the overlying owners, the surplus may be taken for non-overlying use. For distant takers, priority governs relative rights.

This system has been in use for nearly 50 years in California with some amplification of its details but

without change in its fundamental basis. A recent decision (City of Pasadena v. City of Alhambra, 207 P 2d 17) recognized what has been termed mutual prescription for both overlying owners and distant takers, under which the available supply in an overdrawn basin was prorated among all established users of both types. The general effect of this decision will depend on the extent to which its principles may be applied in other areas and under other conditions.

Other western states have found it necessary to define the basis of title to the ground water in their areas. New Mexico has adopted a system of limitation on draft from artesian basins where the state engineer finds the safe yield is being fully used. Idaho follows a system of appropriation for all ground waters as well as for surface streams. Arizona has very recently reconsidered the basis of title applicable to ground-water use (Bristor v. Cheatham, 240 P 2d 185, decision of January 12, 1952—rehearing granted later).

Although the legal principles relating to surface and ground waters are different in many states, physically these two types of water supply may be closely related. The law of surface waters is applied to subterranean streams where they can be identified. The former rule that a subterranean stream must have definable bed and banks has been broadened to include the subflow of a stream where withdrawal from the subflow increases the percolation from the stream. Some streams receive their flow as influent seepage from the adjacent ground water. In other cases the ground water has its source in the effluent flow from the streams. Thus it is difficult to adjudicate equitably between the users of these two types of water supply. Adjustments in such cases can be made more readily if the same basic principles are used for both surface and ground waters.

There are few extended ground-water areas in the arid states in which the naturally available ground-water supply is sufficient to meet the demands of the ultimate consumption of its service area. Unless the outcome is to be left to economic competition, with the less efficient plants dropping out as pumping lifts increase, workable methods of defining rights and controlling use will have to be found and applied.

The general situation regarding the regulation of ground waters is similar to that for surface streams except that it is more difficult to determine and regulate the available supply. On surface streams the number of users is generally limited, and the available supply is accessible for measurement. When the draft on a surface stream exhausts the supply, the result is evident. For ground water there may be several thousand individual users drawing on a supply where overdraft may become known only by its effects after it has occurred for some time. Ground-water users generally obtain their supply from within their own land areas and are accustomed to regarding withdrawals as matters of their own choice. Both the physical and the human problems in regulating ground-water use are much more complex than those for surface streams.

The principles relating to the rights to the use of ground water in California have been adequately defined yet recognized overdrafts are occurring without any attempts to apply these principles through judicial procedure. Ground water has a relatively high value and a continuation of overdraft without seeking to secure limitations on ground-water use must represent some failure in the effectiveness of the principles or in the procedure for their enforcement.

This situation exists because of the difficulty in defining the conditions to which the principles of law can be applied rather than because of any lack of definiteness or reasonableness in the principles themselves. To secure judicial relief it is necessary to define the area of overlying land, the extent of its existing supply, the present extent of use, and the reasonable needs of the existing users. The burden of the proof of these items is so great, the resulting cost of ground-water litigation so high, and the outcome so uncertain that, except in a few instances, the users in California areas have preferred to let economic competition take the place of general adjudication. Overdraft, if continued, results in increased lifts with the less economic uses being forced to give way and to abandon their operation. This situation occurred in some areas during the 1930's but has been offset in recent years by the increased prices received for irrigated crops. In time, the forced reduction in draft will reduce the use to the average replenishment but the process leaves all surviving users subject to the pumping lift at which such abandonment occurred. Limitation of draft at the beginning of development to the average replenishment would have caused the same result as to the amount of permanent use with the advantage of maintaining a much lower pumping lift.

The preceding comments apply particularly to areas of ground-water draft in the San Joaquin Valley. Here the areas supplied from the different sources of replenishment are indefinite and overlapping. It is difficult to prove that draft in one part will produce a definable effect in another part of the area. Relief has been sought by importing additional water supplies. In fact, the Central Valley Project had ground-water replenishment for its main incentive. Relief will, in turn, be a temporary solution unless further increases in use are regulated in some form. The consumptive needs of the areas available for irrigation exceed both local supplies and the importation from the present Central Valley Project.

There has been extended litigation in California over ground water, but this has been mainly between individuals or small groups and there have been no general adjudications of entire ground-water areas. In Southern California one such judicial decision has been made and another one is under way. In both these instances the areas in question have ascertainable boundaries.

Probable Trend in Ground-Water Regulation

The increased knowledge of ground-water hydrology and the increased efficiency of pumping equipment are resulting in a rapid increase in the use of ground water wherever it is available in the western states. This trend is forcing and will continue to force the adoption of methods for the regulation of ground-water use.

In spite of the administrative complexities involved, public interest will insist on some means by which short-lived developments based on excessive overdraft can be avoided. It will be to the best interests of both the ground-water consumers and the public in the different western states if the solutions of these problems are worked out within the background of existing legal principles and with full consideration of the views and interests of the present users. The solutions reached do not need to be uniform in the different states any more than the policy for surface streams needs to be uniform.

How Much Can Established Systems of Water Law Be Changed?

Water rights are real property and a system of title to the use of water when once adopted may not be changed if the change results in the taking of existing property rights without due process of law. Due process of law means taking for a public use and payment for the value of the property taken.

Because of the relatively large values created by the use of water in arid areas, it is impracticable to make radical changes in a system of title to the use of water once it has been confirmed in any area to such an extent that compensation must be paid to established rights. Values will have become fixed by the time development has proceeded far enough to demonstrate the need for change. No reversals in the system of water law requiring compensation have been made in any state after any given system has once become legally recognized.

The foregoing conditions do not mean, however, that principles of water law, when once adopted, become so rigid that modifications may not be made as need for change develops. All property is subject to reasonable regulation. Restrictions can be placed on the use of private property if necessary to prevent injury to others. Such restrictions come within the scope of what is termed the "exercise of the police power." The police power is not limited to the field of water law. Building and zoning ordinances in cities are well-recognized examples of the exercise of the police power.

Restrictions in the Public Interest

Use of property may be restricted without compensation even if the usefulness of the property so restricted is reduced, provided the actions are in the public interest and are required for the benefit of the public. The changes now being made in our water laws mainly come within the scope of regulation of existing rights in the public interest. They are subject to determination by the courts as to whether or not the proposed regulation is non-discriminatory and a reasonable exercise of the police power. In some instances the courts have modified the basis of title used in early development where it was held that the early basis had not been established to the extent that its change constituted a taking of property.

California furnishes an example of two methods of amending the earlier systems to meet later needs. When experience showed that the legislatively adopted system of riparian rights was blocking the effective use of surface waters, a constitutional amendment was passed in 1928 making all uses of water subject to reasonableness. Under the interpretation of this amendment by the courts, riparian owners are now protected in their established riparian titles but use under such titles must be reasonable in relation to methods and amounts. This decision is an example of modifying an established system of title to the use of water by a police-power regulation on its applications.

Ground-water use in California also furnishes an example of a change from an early practice to a different basis of title where the early practice had not become fully established. Early California cases involving ground water were not extensive and did not involve matters of widespread effect. When use of ground water did become extensive about 1900, it was realized that a different rule from that used in early cases was required if equitable results were to be secured and full development of the ground water was to be obtained. The courts recognized this condition and in a thoroughly argued and carefully considered case (Katz v. Walkinshaw, 141 Cal. 116) held that previous cases had not fixed a system of title to ground water in California. The court then proceeded to consider and to adopt the system which it found would best meet the needs of the state.

For some matters in the field of water law, determination of the basis of use has been so incomplete that the courts can now find support for material changes without encountering constitutional prohibitions against the taking of property without due process of law. In certain western states the use of ground water has not reached the point where controversies have resulted in a full definition of the nature of title to its use. In such instances the courts may still be free to approve the adoption by statute or constitutional amendment of the system now considered to be adapted to the needs of such states. Utah, which in 1935 changed from a form of correlative rights to an appropriation system for percolating ground water, is an example in this field.

Water Rights for Federal Projects

Water law in the western states developed on the basis of local construction of local projects. Local forms of public organizations, such as irrigation districts, provided for the construction and management of water projects. There was practically no direct undertaking of water resources development by the Federal Government until the passage of the Reclamation Act in 1902. To date there has been only limited direct construction of state water projects by any of the western states.

The entry of the Federal Government into the water field as a proprietor of new projects introduced many new problems. It was recognized that it was necessary for federal projects to comply with the same conditions for the acquirement and use of water that applied to other owners. Section 8 of the original Reclamation Act required the government to follow state procedure to obtain water rights for its irrigation projects. This principle has been continuously in effect.

The Federal Government has always exercised control over navigable streams under the commerce clause of the federal constitution. To avoid conflict between the use of water to sustain navigation and its use for consumptive purposes, such as irrigation, the 1944 Flood Control Act made navigation in states lying wholly or in part west of the 98th meridian subordinate to the use of water for beneficial consumptive purposes.

It would appear that these provisions would be adequate to require federal water projects to conform with the system of water law in each state. Even on the earlier federal projects, some difficulties arose as federal agencies could, and in nearly all cases did, conduct litigation regarding federal projects in the federal courts.

Over the years, as federal programs covering water projects have been expanded, federal agencies, restive under their obligation to follow state laws, have sought to establish freedom from restraints. Various theories have been developed for this purpose. In several cases, although admitting that the Federal Government must recognize existing rights, federal agencies have contended that the Federal Government still had the right to withdraw unappropriated

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THOMAS A. MIDDLEBROOKS, A.M. ASCE

Head Engineer, Corps of Engineers, and Chief, Soil Mechanics Section, Washington, D.C.

Progress in earth-dam design and construction in the United States

Earth-dam design and construction is one of the oldest branches of civil engineering endeavor. However, the aim here is not to explore the origin of this branch but rather to outline the progress made in it in the United States in the past century.

The most rapid improvement in both design and construction procedures has been made since the introduction of soil mechanics, which caused the rule-of-thumb methods previously used to give way to procedures based on sound theoretical principles. Safe and economical dams and appurtenant structures can now be built on a wide variety of foundations, and embankments can be composed of almost any type of soil or rock, with full assurance that satisfactory performance will result.

Inadequacies which developed in early earth dams designed by rule-of-thumb methods forced engineers to the conclusion that the design of embankments could not be based on a simple base-to-height ratio as employed for concrete gravity structures. Experience confirms the fact that an earth dam with its appurtenant structures must be tailor-made to fit each individual location. Stereotyped plans invariably result in inadequate as well as uneconomical projects.

Although our knowledge during the past twenty-five years has developed greatly, failures still occur. The major reasons why we continue to be plagued with unsatisfactory performance of earth dams were aptly summed up by the late Joel D. Justin,[1] M. ASCE:

> Unfortunately there is a feeling among many people that the design and construction of earth dams are matters so simple that anyone can handle them. Men who employ experts to audit their books will sometimes entrust the design and construction of an earth dam, on the safety of which, perchance, their very lives and fortunes may depend, to anyone at all without inquiring into his competency.

The public must be brought to realize that an earth-dam project must be under the direction of an experienced engineer. Small dams must not be eliminated from this stipulation, since the two failures which caused the greatest loss of life and property were of structures less than 50 ft high. Failure of the Mill River Dam in 1874, which was only 43 ft high, is an outstanding example. Altogether, 143 lives were lost and property damage totaled over $1,000,000 although the project cost only $34,000. No engineers were employed in its design and construction. William E. Worthen,[2] Hon. M. ASCE, a member of the investigating committee, aptly concluded that "a man cannot make a dam by instinct or intuition."

A study has been made of inadequacies of earth dams in both design and construction, bringing up to date the studies made by Justin,[1] the Pennsylvania Power Committee,[3] and others. The list of 206 structures in North America includes not only those usually classified as partial or complete failures, but all those on which remedial work, not contemplated in the original contracts, was necessary. Dams in the United States in this list, which have shown inadequacies since 1914, are included in Table I. The complete list is available from the writer on request. Tables II, III, and IV summarize various phases of the study.

The categories of partial or complete failure given in Table II will now be examined in detail.

Overtopping

There are two major reasons why the spillways of early dams were inadequate. First, data on rainfall and stream runoff were very meager. Second, engineers failed to recognize the amount of risk involved in the occurrence of an unprecedented flood.

Deficiencies in data still constitute a problem to be considered; however, they can hardly be an excuse for inadequate design today in the continental United States. Experience has shown that under-designed spillways present too great a hazard in most cases for enginers to design for anything less than the maximum probable flood.

Usually the possible loss of life and property damage which would result from overtopping is so great that a calculated risk cannot be tolerated. For example, failure of the South Fork Dam (Johnstown Flood) in 1889 resulted in the loss of 2,280 lives and property damage of over 3 million dollars, whereas the dam cost only $167,000.

Gail A. Hathaway, Past-President of ASCE, has pioneered the increase in our knowledge and the development of better methods of computing spillway design floods. He has in-

Typical successful earth structure built to protect a highly developed valley from floods is Youghiogheny Dam located above city of Confluence, Penn. It is constructed of shale from spillway excavation in combination with overburden clays.

sisted on eliminating the calculated risk premises of design. If the methods for computing the maximum probable flood and the required freeboard as outlined by Hathaway and Cochran in *Engineering for Dams*[4] are followed, a structure safe from overtopping is assured.

Failures due to overtopping, as noted by Tables III and IV, are reasonably well distributed. The grouping of failures between 10 and 20 years after construction, as shown in Table III, is probably due to the fact that the design was generally based on a storm having approximately this frequency of occurrence.

Seepage

The famous "creep" theory and the crude principle of "inclosing" the saturation (phreatic) line within the embankment have given way to sound soil mechanics principles of seepage control. Darcy's law, developed about 1850, forms the basis for all modern methods of seepage analysis. The flow-net method of analysis, pioneered in this country by Casagrande,[5] is now widely used. The first published attempt to rationalize seepage under dams was made by Koenig in 1911.[6] He attributed failure to buoyed-up particles at the seepage exit.

One of the earliest seepage model studies was made by Colman in 1916.[7] Following shortly thereafter, Hays presented a paper[8] on the use of seepage models in the design of dams.

Seepage through embankments is usually controlled by proper zoning of the available embankment materials. An ideal embankment section is one composed of a relatively narrow central impervious core (Fig. 1, section *a*) supported by well-graded, free-draining shells of pervious material. The free-draining upstream material assures the safest and most economical slopes which can be designed to protect against drawdown forces. The pervious downstream section, with an adequate transition or filter zone, insures a low saturation line and full control of through seepage. Hydraulic and puddle core fills with sand and gravel shells were the earliest dams of this type.

Great progress has been made in the design of earth dams on deep pervious foundations. In the early days earth dams were limited principally to sites where positive cutoffs to an impervious stratum could be obtained. It is believed that the Gatun Dam was the first large dam to be constructed over a deep pervious foundation without a positive cutoff. The design was based on a long path of seepage and a downstream rock drainage toe. The principle now widely used of designing an impervious upstream blanket and downstream drainage (Fig. 1, section *d*) was first proposed by Hays in 1917.[8]

Design methods based on theoretical seepage analyses are now available for determining the optimum width of impervious blankets[9] and provisions for downstream relief wells.[10] In stratified pervious deposits which include the bulk of natural formations, relief wells have been found to give most satisfactory results at a low cost.

Positive control of seepage through the embankment and foundation is an essential requirement in earth-dam design. Uncontrolled seepage, regardless of the amount, should not be tolerated. Seepage through the embankment is controlled by a pervious zone having the required gradation to form a stable filter. This zone may take the form of a pervious downstream section, a horizontal or inclined pervious drainage blanket, or a toe drain. See Fig. 1. Proper filter characteristics of all the materials involved in foundation and embankment are essential to prevent piping and thereby to insure a safe structure. Terzaghi, in an unpublished report, and Bertram[11] were the first to establish satisfactory filter criteria.

Foundation seepage is preferably controlled by a positive impervious cutoff to an impervious stratum with a drainage blanket or trench to collect whatever seepage may occur through the bedrock and embankment. Where a positive cutoff cannot be obtained, careful design of a relief-well or toe-drainage system together with an upstream impervious blanket is necessary. Steel sheetpiling, used extensively in early earth-dam construction, cannot be depended on to reduce seepage appreciably. At Fort Peck Dam,[12] although the steel sheet-pile cutoff was driven entirely through the pervious foundation, pressure from seepage through the cutoff developed a 40-ft hydrostatic head above the ground surface at the downstream toe and relief wells had to be installed. At Denison Dam in Texas, steel sheetpiling was also ineffective in reducing seepage.

In addition to normal seepage through the soil mass, the pervious zone should be adequate to control seepage from a crack which might develop through the impervious zone. To provide greater protection against formation of cracks, at least the center portion of the impervious zone should be compacted on the wet side of optimum placement moisture so that this mass will be plastic and will not consolidate further when completely saturated. Cracks through dams have long been recognized as a problem and have probably been the cause

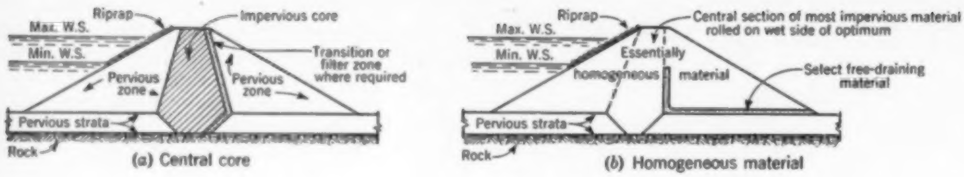


FIG. 1. Typical successful embankment sections utilize (a) central impervious core, (b) homogen-

of many "piping" failures, but only recently has a complete study been made by Sherard,[13] sponsored by the Bureau of Reclamation, on the performance of dams from this standpoint.

Permeability tests to determine the seepage characteristics of different soils were first conducted independently by the Massachusetts State Board of Health and D. C. Henny (Oregon) in 1907. It was the earlier concept that the slope of the saturation line was governed by the material. As late as 1930, many dams and levees were designed on the basis of containing the saturation line. Progress in this field was rapid in the 1930's. It is believed that the piping phenomenon mentioned by Koenig in 1911[6] was first comprehensively treated by Harza in 1936.[14]

Conduits

Unsatisfactory performance of conduits has been due principally to the following three deficiencies in design or construction:

Piping along conduit due to absence of seepage collars, or poor compaction around conduit

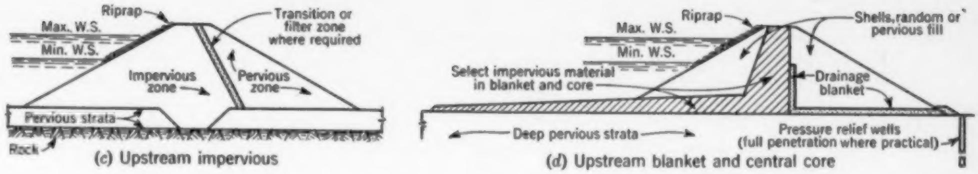
Failure of conduit due to unequal settlement where pipe was supported on piers or where settlement was uneven

TABLE I. Unsatisfactory Performance of Earth Dams in United States, Since 1914

Name of Dam and Location	Date: Built	Date: Failed	Reference*	Height	Type	Reason for Unsatisfactory Performance
Anaconda, Mont.	1898±	1938	ENR, vol. 121	...	Earth, concrete core	Overtopped
Apishapa, Colo.	1920	1923	ENR, vol. 91	115	Earth, rolled	Piping through settlement cracks
Balsam, N. H.	1927	1929	ENR, vol. 54	60	Earth, concrete core	Erosion from spillway
Belle Fourche, S. Dak.	1911	1933	ENR, vol. 111	122	Earth, rolled	Drawdown slide, concrete slope paving failure
Calaveras, Calif.	....	1918	ENR, vol. 80	240	Hydraulic	Excessive core pressure
Davis Reservoir, Calif.	....	1914	EN, vol. 72	39	Earth, rolled	Piping around outlet
Dry Creek, Mont.	....	1939	ENR, vol. 122	46	Earth, rolled	Piping
Elk City, Okla.	1925	1936	ENR, vol. 116	30	Earth, rolled	Overtopped
Fairview, Mass.	....	1922	ENR, vol. 89	30	Earth, rolled	Piping
Fort Peck, Mont.	....	1938	ENR, vol. 121	250	Hydraulic	Foundation slide
Fruit Growers Res., Colo.	1898	1937	ENR, vol. 118	36	Earth, rolled	Seepage slide
Garza, Tex.	1926	1926	ENR, vols. 94, 100	80	Hydraulic	Core pressure slide
Goose Creek, S. C.	1903	1916	EN, vol. 76	22	Earth, rolled	Overtopping
Half Moon Bay, Calif.	....	1926	ENR, vol. 96	80	Earth, rolled	Overtopping
Hebron, N. Mex.	1913	1914	ER, vol. 69	56	Earth, rolled	Piping through dam
		1942				
Horse Creek, Colo.	1911	1914	ER, vol. 69			Overtopped, not repaired
			EN, vol. 71	56	Earth, rolled	Piping
Horton, Kans.	1924	1925	ENR, vol. 95	34	Earth, rolled	....
Killingsworth, Conn.	....	1938	ENR, vol. 121	18	Earth, concrete core	Overtopping
Lafayette, Calif.	1929	1928	ENR, vol. 54	140	Earth, rolled	Foundation slide during construction
La Fruta, Tex.	1930	1930	ENR, vols. 105, 106, 107	61	Earth, rolled	Foundation piping
Lake Dixie, Tex.	....	1940	ENR, vol. 125	...	Earth, rolled	Overtopped
Lake George, Colo.	....	1914	ASCE Proc., vol. 49	...	Earth, rolled	Piping
Lake Toxaway, N. C.	1902	1916	ENR, vol. 94 ER, vol. 74	62	Earth, rolled	Seepage
Linville, N. C.	1919	1919	ASCE Trans., vol. 84	160	Hydraulic	Core too flat
Lock Alpine, Mich.	....	1926	ENR, vol. 96	25	Earth, rolled	Settlement upon being saturated
Lower Otay, Calif.	1897	1916	EN, vol. 75	130	Rock, concrete core	Overtopping
Lyman, Ariz.	1913	1915	EN, vol. 73	65	Earth, rolled	Piping
Mammoth, Utah	1912	1917	ENR, vol. 79 ER, vol. 66	70	Earth and hydraulic	Overtopped during construction
Maquoketa, Iowa	1924	1927	ENR, vol. 98	20	Earth, rolled	Piping at junction with concrete spillway
Marshall Creek, Kans.	...	1937	ENR, vol. 119	80	Earth, rolled	Foundation failure during construction
Martin Davey Dam, Tex.	....	1940	ENR, vol. 125	...	Earth, rolled	Overtopped
Mission Lake, Kans.	1924	1925	ENR, vol. 95	...	Earth, rolled	Settlement with overtopping
Mohawk, Ohio	....	1913	EN, vol. 73	18	Earth, rolled	Overtopped
		1915	EN, vol. 73	18	Earth, rolled	Settlement and seepage
Mount Lake State Park, Minn	1937	1938	ENR, vol. 120	...	Earth, rolled	Overtopped
New Bowman, Calif.	1927	1928	ENR, vol. 54	170	Rock	Break in outlet tunnel—repaired
Peapack Brook, N. J.	....	1928	ENR, vol. 100	32	Earth, rolled	Overtopped
Pleasant Valley, Utah	....	1928	ENR, vol. 100	63	Earth and rock	Piping through settlement cracks
Providence, R. I.	1816	1916	EN, vol. 45	17	Earth and rock	....
Puddingstone, Calif.	....	1926	ENR, vol. 96	..	Hydraulic	Overtopped during construction because of clogged outlet
Schenectady, N. Y.	....	1916	EN, vol. 76	30	Earth, rolled	Overtopped
Scofield, Utah	1926	1927	ENR, vol. 100	62	Earth and rock	Transverse cracking and piping into rock
Seluda, S. C.	1930	1930	ENR, vol. 104	208	Hydraulic	Core pool lost during construction
Sepulveda, Calif.	....	1914	ER, vol. 74	65	Earth, concrete core	Overtopped
Sheffield, Calif.	....	1925	ENR, vol. 95	30	Earth, rolled	Earthquake
Short Creek, Ark.	....	1939	ENR, vol. 122	57	Earth and rock	Overtopped during construction
Sinker Creek, Idaho	1910	1943	ENR, vol. 113	70	Hydraulic and earth	Seepage slide
Standley Lake, Colo.	1911	1916	ENR, vol. 78	113	Hydraulic	Core too large—slides during and after construction
Table Rock Cave, S. C.	1927	1928	ENR, vol. 100	140	Earth, rolled	Broken outlet pipe
Turlock Irrig., Calif.	....	1914	....	56	....	Leakage around outlet
Virgin River, Nev.	....	1929	ENR, vol. 103	120	Earth, rolled	Poor design and construction
Wagner, Wash.	1918	1938	ENR, vol. 120	50	Hydraulic	Spillway failure
Wister, Okla.	....	1951	....	90	Earth, rolled	Piping
Wise River, Mont.	....	1927	ENR, vol. 99	...	Earth, rolled	Overtopping

* ENR = *Engineering News-Record*; EN = *Engineering News*; ER = *Engineering Record*; ASCE Proc. = ASCE *Proceedings*; ASCE Trans. = ASCE *Transactions*.

eous material, (c) upstream impervious zone, and (d) upstream blanket and central core.



Failure of conduit due to inadequate strength to resist earth pressure

In current design all these deficiencies have been corrected. Seepage collars are provided on all conduits and compaction of the fill around the conduit is most carefully controlled. Anticipated settlement is closely estimated and the conduit is designed for this settlement. Wherever practical, conduits are placed on rock to reduce settlement to a minimum. Present structural design criteria are generally very conservative.

It is not expected that conduits will be a source of unsatisfactory performance in the future. Past experience indicates that if trouble with a conduit occurs it will be within the first few years after construction (see Table III). New designs are sufficiently conservative to insure satisfactory performance. It should be noted from Table IV that there have been no conduit failures in the past 20 years.

Slides

Rational methods for determining the stability of earth slopes were slow in developing because of the lack of adequate testing apparatus and procedure, and of adequate analytical methods.

Bell's paper[15] in 1914 and Cain's[16] in 1916 are believed to be the first published works in this country on tests made to determine the strength of soils. Following this work, there was a gap of almost 20 years before shear testing was applied generally to earth-dam construction. Hatch's paper[17] in 1934, Jurgenson's[18] in 1934, and Gilboy's[19] in 1936 were probably the first published works covering the concerted efforts in the United States toward soil testing for strength determinations essential for use in slope stability studies.

Outstanding progress has been made since this earlier work by practical testing on the job such as that at Muskingum and Fort Peck dams reported by Philippe[20] and Middlebrooks,[21] and the extensive research work conducted in university and government laboratories. Probably the most comprehensive research was conducted at Harvard, M. I. T., and the Waterways Experiment Station under the direction of the Corps of Engineers and reported by Rutledge.[22] The best and most up-to-date treatment on soil testing can be found in publications by Casagrande and Fadum,[23] Lambe,[24] and the Bureau of Reclamation.[25] Knowledge and techniques on soil testing are adequate for the satisfactory solution of all practical problems.

Terzaghi's paper[26] in 1929 was the first attempt in the United States to outline a theoretical method of slope stability determination. Rapid development was made in the 1930's, reaching a climax about the time of the Second Congress on Large Dams held in Washington, D. C., in 1936, and the First International Conference on Soil Mechanics held in Boston in the same year. Outstanding papers on stability, using the Swedish circular-arc method, during this period were presented by Gilboy,[27] Casagrande,[28] Terzaghi,[29] and Taylor.[30] Charts for slope stability presented by Taylor at that time are still widely used for preliminary examination of slope stability.

Also during the 1930's there was in process of development a truly scientific method of analysis, as differentiated from the empirical circular-arc method, based on the application of the theory of elasticity. The first papers presenting this method were

TABLE II. Causes of Inadequacies of Earth Dams Summarized

Cause of Partial or Complete Failure	Percentage of Total
1. Overtopping	30
2. Seepage	25
3. Slides	15
4. Conduit leakage	13
5. Slope paving	5
6. Miscellaneous	7
7. Unknown	5

TABLE III. Relation of Failure to Age of Structure, in Percentage of Total Number of Structures

No. of Years After Completion	Cause of Difficulty: Overtopping	Conduit Leakage	Seepage	Slides
0– 1	9	23	16	29
1– 5	17	50	34	24
5– 10	9	9	13	12
10– 20	30	9	13	12
20– 30	13	5	12	12
30– 40	10	4	6	11
40– 50	9	0	6	0
50–100	3	0	0	0

TABLE IV. Chronological Distribution of Failures

Calendar Year	Overtopping, %	Seepage, %	Conduit Leakage, %	Slides, %	Total* %
1850–1860	0	0	0	0	0
1860–1870	0	0	7	0	1
1870–1880	0	6	7	0	3
1880–1890	6	4	11	3	5
1890–1900	12	11	21	8	13
1900–1910	23	19	18	16	17
1910–1920	22	25	18	23	21
1920–1930	14	13	18	26	16
1930–1940	11	8	0	23	10
1940–1950	9	6	0	3	8
1950	3	8	0	3	4

* Includes all inadequate dams even though cause of unsatisfactory performance was not determined.

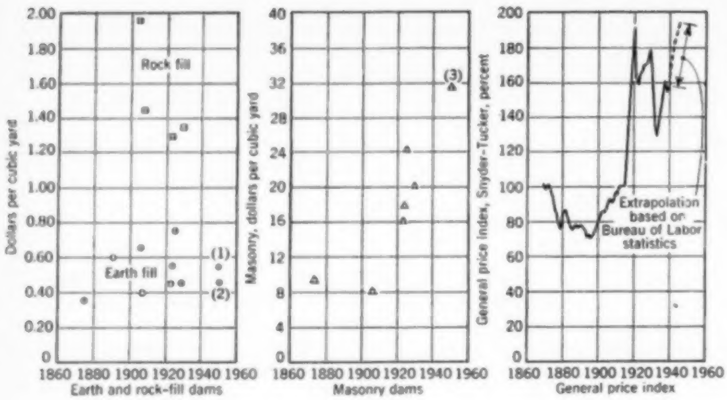


FIG. 2. Costs per cubic yard for earth- and rock-fill dams and masonry dams are compared with general price index according to Snyder-Tucker (1913 = 100 percent). Unnumbered points are for individual dams. Numbered points have special significance, as follows: (1) average of 15 western projects; (2) average of 90 contracts over entire United States; (3) average of 21 contracts over entire United States.

by Jurgenson[31] in 1934, Knappen and Philippe,[32] and Middlebrooks[33] in 1936. The general reaction at that time was one of astonishment that any engineer would seriously consider soil sufficiently elastic to apply this theory. All the research conducted since that time has added strength to the contention of the proponents of this method that, although soil is not perfectly elastic, its stress-strain characteristics are such that stresses computed by this theory are sufficiently accurate for most practical problems.

Liquefaction of cohesionless soil as a problem in the design of dams was first published in this country by Casagrande[28] in 1936. There was a tendency at this time to classify some normal shear failures as flow slides. A notable example was the Fort Peck slide[34] which occurred in 1938. The first reaction of some engineers was that it was a flow slide due to liquefaction of the hydraulic fill. After extensive investigation, the consulting board concluded that the slide was "due to the fact that the shearing resistance of the weathered shale and bentonite seams in the foundation was insufficient to withstand the shearing forces to which the foundation was subjected." It is generally accepted at the present time that for a cohesionless soil to liquefy and cause a flow slide it must be very loose and uniform. Even with only a moderate degree of compaction of uniform sands, there is no danger of a flow slide in a dam, and there is no record of a slide being caused by liquefaction of the foundation sand under an earth dam.

Types of Construction—Rolled Fills

The compacted fill is the oldest type of earth-dam construction. Wagons and scrapers were the principal means of placing the material in the earliest dams built in this country. In most cases compaction was obtained during the normal hauling operations by spreading the material in thin layers. The South Fork Dam in Pennsylvania built in 1853 is a good example of the best construction practices at that time. The specifications[35] for this dam were excellent considering that they were written 100 years ago. Some of the essential features of the South Fork specifications provided for placement in layers, compaction with carts and wagons during normal hauling operations, and prohibition of barrows, chutes, and railway equipment. Scarifying of foundation and lifts was required; stones over 4 in.

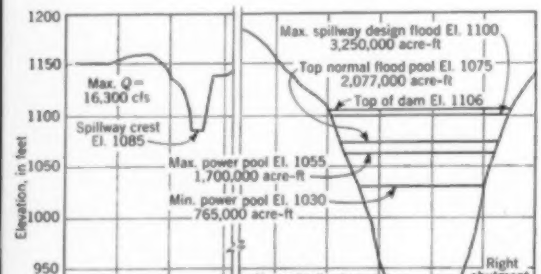
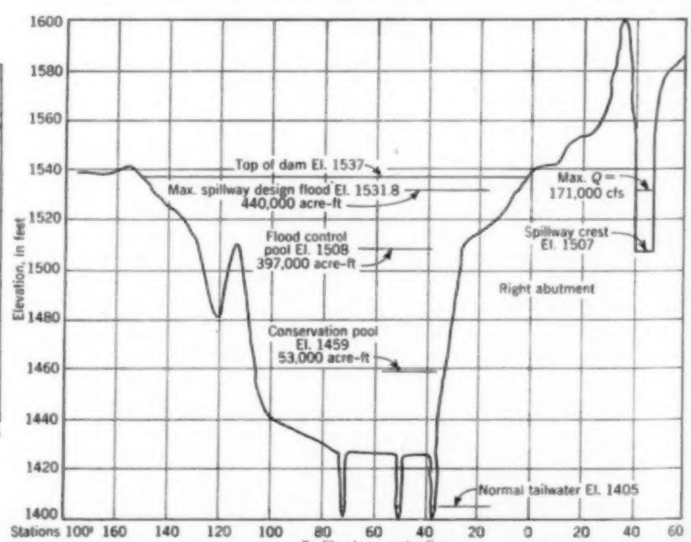


FIG. 3. Buford Dam is outstanding example of present tendency to store large part of spillway design flood, using emergency spillway in form of unpaved cut through low saddle. In this case it was $5,000,000 cheaper to raise earth dam 40 ft to take advantage of favorable saddle in left abutment than to build concrete ogee spillway in river at lower level. Project will provide 100 percent flood protection since at maximum storm only small discharge passes over spillway.

FIG. 4. Kanopolis Dam is typical of projects designed with unpaved spillway which will have more frequent use than that at Buford Dam, Fig. 3.



in diameter were excluded; downstream rock fill was required to be "of such nature as to resist the decomposing action of air, frost and water"; the use of a transition zone between rock and rolled earth was required, the earth to "be composed of best watertight material within 1/4 miles of dam" and the core to be puddled if necessary to obtain an upstream impervious zone.

Compaction as an essential feature in earth-dam design and construction received only periodic acceptance before 1900. However a pamphlet[36] published by *Engineering* in 1868 and a paper by McAlpine[37] in 1877, stressing the importance of compaction in layers, were major steps in the development of an awareness of the need for special compaction equipment.

Use of special rollers for compaction has developed steadily since the first heavy smooth roller was used about 1860. About 1905, the sheepsfoot roller was first used in the Western States and this started a gradual but general recognition of compaction as an essential feature of earth-dam construction. However, wide acceptance of compaction and moisture control was not realized until the early 1930's. From its introduction until the late 1940's, efforts were devoted to improving the sheepsfoot roller as a compaction unit. During this period the smooth roller was abandoned and the size of the sheepsfoot roller was increased from a total weight of 10,000 lb for a double drum roller to approximately 42,000 lb. The heavy roller was first used by the Los Angeles Flood Control District and shortly thereafter was adopted as standard equipment by the Bureau of Reclamation for the compaction of cohesive soils.

The latest trend in roller development is the medium weight (50,000- to 100,000-lb) four-wheel rubber-tired roller, the specifications for which were developed by the Corps of Engineers under the direction of Bertram. All earth construction contracts of the Corps of Engineers permit the contractor to use either a 42,000-lb double drum sheepsfoot roller or a 100,000-lb (25,000 lb per wheel) rubber-tired roller for the compaction of cohesive soils. The rubber-tired roller is specified for the compaction of cohesionless soils. Specifications are usually written to allow layer thicknesses approximately twice those allowed for sheepsfoot rollers with one-half the number of passes. Experience to date indicates that the rubber-tired roller generally gives somewhat greater density at a saving of 2 to 5 cents per cu yd. Larger savings are realized in rocky soil where removal of oversize stones is an expensive operation. In these soils the rubber-tired roller permits placement in 18- to 24-in. layers. It is predicted that the rubber-tired roller will gradually replace the sheepsfoot for compaction of all types of soil.

Moisture control, long recognized as an important feature in embankment construction, has only in recent years received the attention it deserves by reason of its importance in the stability of the structure. In the early years of earth-dam construction, puddling was the favored method for placing the core, the rest of the dam being placed at the natural moisture content or with only a moderate degree of moisture control. Shortly after the turn of the century, Bassel[38] and Schuyler[39] were active supporters of moisture control. The Proctor[40] test revolutionized the moisture and compaction control of embankments. At present there are two schools of thought, one favoring compaction on the dry side of optimum moisture to eliminate high pore pressures, and the other favoring compaction on the wet side of optimum to prevent cracking, which may develop continuous seepage passages. Based on experience with earth dams and levees placed on the dry side of optimum, the Corps of Engineers favors placement of all earth-dam embankments on the wet side of optimum and requires that the core or central portion of the impervious section be placed at a moisture content and density which will not allow any additional consolidation on saturation. Use of these criteria usually results in placement of the core material well on the wet side of optimum moisture. Full consideration must be given in the stability analysis to the pore pressure that will be developed. Hilf,[41] in reporting on work of the Bureau of Reclamation, outlined a method of estimating these pressures.

Hydraulic Fills

The hydraulic-fill method is exclusively an American development and was pioneered by Schuyler, Howells, and Gerig. The first hydraulic-fill methods were adapted from hydraulic mining processes. Dorsey's[42] paper in 1886 proposing the use of mining methods in excavation and placement of fills is the first published work in this field. It is believed that Anderson[43] in 1893 was the first to propose the use of a sluiced fill for a dam. Howells[44] in 1895 was probably the first to build a hydraulic-fill dam. Schuyler[45,46] probably was the first to propose construction methods based on actual experience.

After several failures due to excessive core pressures, there was a trend toward extremely flat slopes. Schuyler considered this trend unjustified and pointed out in his 1907 paper[46] "that in his experience there was no reason for building a dam of greater dimensions because the material was placed by hydraulic methods." Hazen in his article[47] in 1919 stated, "If core material can be fully drained and consolidated, there is no reason why a dam built by the hydraulic method on a section that is suitable for an earth dam built dry should not be safe."

Holmes[48] in 1921 was probably the first to consider soil characteristics in the design. Paul's paper[49] in 1922 was the first comprehensive coverage of problems relating to the core. However, it was over ten years later before rational testing and analytical methods were proposed. Gilboy's papers[50,51] in 1933 and 1934 clearly outlined the principles involved in hydraulic-fill dams and proposed a method of determining the stability of the shells which is still widely used. Hatch in his paper[17] proposed methods of tests for hydraulic-fill materials which were most useful at that time.

When designed and constructed in accordance with the latest soil mechanics practices, the hydraulic fill will give equally as satisfactory a performance as the rolled fill. Immediately after the Fort Peck slide in 1938 there was a tendency to discount the hydraulic fill. However, after full data became available from the slide investigation, it was shown that the slide was due to a weak foundation, and not to the hydraulic fill. Nevertheless there have been no new hydraulic-fill dams constructed since Fort Peck, Sardis, and Knightville dams, which were completed by the Corps of Engineers over ten years ago. A number of potential hydraulic-fill dams have been investigated in recent years, but all have proved more costly than the rolled fill. The improvement in earth excavating, hauling, and compaction equipment has reduced the cost of rolled fills to such a degree that hydraulic fills cannot compete unless circumstances are exceptionally favorable.

Rock Fills. The rock-fill dam has given the most satisfactory performance of all types. There is no record of a major rock-fill dam breaching from any cause other than overtopping. Attention is invited to the fact that only a few rock-fill dams appear in the compilation of failures in Table 1.

Rock-fill dams constructed with an impervious upstream earth section do not have as satisfactory a performance record as the plain rock fill with an impervious facing. Frequent piping of the earth fill into the rock fill has been due to inadequate transition zones. Modern dams having an upstream impervious earth section, a sloping or a central core have an excellent performance record since the transition zone is carefully designed and constructed.

Settlement of rock fills is slight, averaging less than 1.0% of the height. Under present construction practice these fills are sluiced with 1.0 to 2.0 cu yd of water per cubic yard of rock when dumped, or where soft rock is used in construction, they are compacted with heavy rollers.

Core Walls and Cutoff Walls. The earliest dams constructed in this country followed the English practice of using a puddled clay core. Because of the low stability and the difficulty of placing the puddled core, it was replaced first by a masonry, and later by a concrete, core wall. The concrete core wall was never generally accepted. Experience showed that these walls invariably cracked and failed to provide the desired watertightness. Instead of following the practice of some foreign engineers of providing a puddled clay layer for watertightness upstream from the concrete core wall and a filter layer downstream to prevent loss of the puddled clay through the cracks, the American engineers gradually changed to rolled earth cores. Apparently, the last concrete core wall was constructed in this country about 25 years ago. It is believed that there are no conditions which justify the use of a concrete core wall in a modern earth- or rock-fill dam.

Concrete cutoff walls, extending above the rock foundation from 5 to 50 ft into the earth core, are still used to a limited extent. The cutoff walls are merely carryovers from the concrete core wall, and it is expected that their use will be discontinued in the near future. Preferred practice in modern dam design and construction is to place the core directly on the rock or impervious foundation. The width of core at the contact is usually about 25 percent of the net head and special care is taken in placement of materials in the contact zone.

Slope Protection

Riprap has been the material most generally employed for upstream slope protection since the earliest dams. Other methods have been tried, but few have been as successful or as economical. On the Santee Cooper Dam[52] the porous concrete slope protection, which seemed to have much promise, deteriorated in a few years to such an extent that it had to be replaced with riprap in the active pool zone. The articulated concrete slabs used on the Kingsley Dam[53] failed during the first major storm, because the sand fill was pulled out from behind them. It is possible that this articulated concrete slope protection would have been satisfactory had an adequate filter layer been placed under it, as the design required. Continuously reinforced concrete slabs have been installed on some western dams,[54] and their performance has been entirely satisfactory.

Until a few years ago very little progress had been made in establishing design requirements for riprap. It was fairly general practice to place dumped riprap 3 ft thick on all dams regardless of exposure, fetch, or slope, and to consider that 18 in. of hand-placed riprap was equivalent to 3 ft of dumped riprap.

Since slope protection is a major item of cost in the construction of earth dams, the Corps of Engineers instituted a performance survey in 1946 covering the bulk of the major dams in this country, and published a report[55] in 1949. The highlights reported are: riprap requirements as to thickness and size of stone are very conservative; hand-placed riprap is not as satisfactory as dumped riprap; and a filter layer underneath riprap is essential. The latest riprap requirements for embankments used by the Corps of Engineers vary from a 12-in. thickness (maximum 200-lb stone) where wave height is less than 2 ft, to a 30-in. thickness (maximum 2,500-lb stone) where the wave height is 8 ft. Use of these requirements has resulted in substantial savings in earth-dam projects.

The above requirements apply to slopes steeper than 1 on 5. Additional work is needed to determine the slope-protection requirements for slopes between 1 on 5 and beach slopes of 1 on 15 to 20. At the present time the thickness, size, and quality of riprap are arbitrarily reduced when flatter slopes are involved.

None of the theories at present available are adequate for computing riprap thickness and size; however, it is anticipated that a more scientific approach will become available in the near future.

Earthquakes

Performance of earth dams during earthquakes has been more satisfactory than is generally assumed. In the 1906 San Francisco earthquake no earth dam was seriously damaged although three water supply dams were in the area of highest intensity. These dams[56] were Temercal, Pilarcitos, and San Andreas. The San Andreas Dam was adjacent to the San Andreas fault, and although there was a displacement in the abutment, which sheared the outlet conduit, the dam was not seriously disturbed. The steepest downstream slope on these dams was 1 on $2\frac{1}{2}$. All these dams were on relatively strong foundation materials.

The only earth dam in this country on which there is a positive record of failure during an earthquake is the Sheffield Dam near Santa Barbara, Calif. It was thought by some that this failure was a typical foundation flow-slide failure due to liquefaction of fine sand or silt, set off by the earthquake. A special study of this dam was made by the Corps of Engineers and a report[57] issued in 1949. The conclusions are: (1) failure was due to a weak zone in the foundation; (2) the 1 on $2\frac{1}{2}$ downstream slope had a factor of safety of less than 1.0 when a factor of $0.10g$ was included as a horizontal force in the stability analysis. The foundation was composed of clayey sand and sandy silt overlying sandstone. There was no stripping of the foundation nor any drainage provided under the downstream slope.

It is the policy of the Corps of Engineers[58] to check the design of all earth dams in areas subject to earthquakes to be certain that the factor of safety is greater than 1.0 when earthquake forces are applied. In checking the stability, it is recommended that factors of $0.05g$ be used for earth dams on rock foundations and $1.10g$ for those on weak soil foundations.

Costs

Cost data have been reviewed and the results included as Fig. 2 to show the general trend in the past century. Only the three major items—earth fill, rock fill, and masonry or concrete—have been included. Earth-fill prices vary widely depending on the material, the job, and the location and for that reason there is considerable scattering of the points. Nevertheless, it is evident that over the past 100 years, earth-fill costs have remained constant or have shown a slight decrease, while at the same time the general price index has increased

from a low of about 70 in 1895 to a high of about 195 today. This is a tribute to the equipment and contracting industries and the role they have played in improving excavating, hauling, and compaction equipment and construction techniques.

Masonry prices have shown a steady increase in the past 50 years, paralleling a reasonably close increase in the price index, which has now reached about $2^1/_2$ times the low of 1895.

A Look Into the Future

Spillways. Even in this modern age overtopping of earth structures can be expected. Older structures not designed by the new concepts will eventually be hit by an unprecedented storm which will exceed the capacity of the spillway and failure will occur. Also, new structures are still being built with under-designed spillways, and following the laws of probability some of these dams will also be overtopped. The writer recommends most strongly that the spillway capacity and freeboard requirements on all old dams be reviewed in the light of modern theory and knowledge, and that the dams be raised or the spillways enlarged to accommodate the maximum probable flood without overtopping. The engineers responsible for such dams in both public and private ownership should not wait for failures to force these changes by an aroused public opinion. It is predicted that the under-design of spillways will not be tolerated in the future on any dams where loss of life and heavy property damage might result.

It is further predicted that, in the not too distant future, spillways will be safely and economically designed and constructed over earth dams. The foundation afforded by a modern compacted embankment is superior to many of our natural earth abutment foundations. Settlement can be eliminated as a problem by constructing the fill to a predetermined surcharge elevation and allowing time for consolidation to occur before constructing the spillway.

In view of the high cost of reinforced concrete structures and the demand for complete protection against overtopping, it is predicted that the use of formal concrete spillways will be reduced to a minimum. More and more dams will be designed to store a large part of the spillway design flood, and an emergency spillway, consisting only of a concrete sill in an unpaved cut remote from the dam, will prove satisfactory in view of its infrequent use.

The Corps of Engineers has many such dams planned or under construction. The Buford Dam on the Chattahoochee River now under construction is an outstanding example of this type of construction (Fig. 3). In this case it was 5 million dollars cheaper to raise the earth dam approximately 40 ft to take advantage of a favorable saddle in the left abutment than it was to build a concrete ogee spillway in the river at a lower level. This project will provide 100 percent flood control, since only a small discharge passes over the spillway with the occurrence of the maximum probable storm.

The Kanopolis Dam (completed in 1947) is a project typical of an unpaved spillway which will have more frequent operation (Fig. 4). Other dams of similar design are Blakely Mountain near Hot Springs, Ark., Cherry Creek Dam near Denver, Colo., Bayou Bodcau near Shreveport, La., Buffalo Bayou near Houston, Tex., several of the Muskingum group of dams in Ohio, and the Merced group of dams in California. The Bureau of Reclamation has several dams with similar design, and many small earth dams are being constructed by the Soil Conservation Service with unpaved spillways.

Seepage. It is predicted that in future designs made under the direction of experienced engineers, seepage will be eliminated as a source of possible trouble. Failures from this source will be rare since most old dams have been tested, and new dams will be designed to control all leakage through the dam as well as through the foundation and abutments. However, some failures can be expected of old dams that have not yet been subjected to the maximum reservoir level. Relief wells will be widely adopted for foundation seepage control because of their efficiency and economy. Proper zoning of available material, or use of thin drainage blankets, will be generally adopted as the most economical means of controlling seepage through dams.

Conduits. Modern design and construction of conduits assure that no new failures will occur from this source. Adequate wall thickness eliminates the danger of collapse. Rubber water stops and collars at all joints protect against leakage into or out of a conduit. Seepage collars and careful compaction of backfill assure that detrimental leakage will not occur along the conduit. Stilling basins are added where necessary to eliminate any troublesome scour.

However, conduits designed by present criteria are unnecessarily conservative, and in many cases add a burdensome cost to the project. It is predicted that the structural design of reinforced concrete conduits will be drastically revised with the result that structures will be both more economical and safer. It is further predicted that on more and more dams, particularly the smaller projects, stilling basins will be omitted. The discharge end of the conduit will be so designed that scour will not cause excessive maintenance or serious erosion. It is interesting to note that there is no record of a dam failing, or of serious trouble developing, as a result of scour from this source. Considerable economy can be realized on earth-dam projects by giving careful consideration to these overlying features of conservative design.

Stability. Our present knowledge is such that stability should be eliminated as a future source of inadequate design on all new projects. Our knowledge is adequate to design for any known condition. It is therefore up to the engineer to obtain adequate data on embankment and foundation conditions and then to apply our present knowledge correctly. Some trouble from slides in old dams that have not been fully tested can be expected, as is evident from the percentages in Table II.

Criteria for Design and Construction

Based on past experience and our present knowledge of design, the following criteria are considered essential for the construction of an earth dam which will be unquestionably safe:

1. Spillway capacity and freeboard should be sufficient to prevent overtopping when the maximum probable flood occurs.
2. Foundation and embankment should not be overstressed in shear.
3. Seepage through dams should be controlled by proper zoning of materials or the use of pervious drains. The use of pipe drains within the embankment section should be avoided.
4. Foundation seepage should be controlled by positive means such as an impervious cutoff to bedrock (not sheet-piling), or seepage controlled at exit downstream by relief wells or a drainage trench.
5. Conduits should be conservatively designed to prevent collapse, leakage from or into the conduit, and seepage along the conduit.
6. Slope protection should be provided to the crest of the dam to protect against breaching of the embankment during a major storm.
7. At least the central portion of the

impervious section should be compacted to a density that will not produce settlement on saturation.

8. Careful design and construction should assure that there are no continuous seepage passages, such as might be caused by failure to bond and properly compact succeeding layers; by allowing zones or layers of pervious materials to extend through the embankment; by failure to properly bond the embankment to the foundation; or by failure to provide a tight contact between the earth fill and concrete structures.

9. Development of cracks in the embankment due to foundation or fill settlement should be avoided by proper consideration of slopes of abutments, riverbanks, and closure sections and by proper placment of fill material. Special attention should be given to the core or central part of the impervious section to assure that the mass will be sufficiently plastic to deform without cracking.

Some dams may not meet all these criteria, and based on past experience their safety is questionable until fully tested by time and high reservoir levels. On the other hand, it can be stated that any dam which *does* meet all these criteria will have an adequate margin of safety against unsatisfactory performance.

Each year an increasing percentage of the dams constructed in the United States are built of earth. This increase in the number of earth dams is due principally to three major factors:

(1) The science of soil mechanics has developed to the extent that equal confidence can be placed in the performance of earth dams as compared to other types.

(2) The cost differential between earth and concrete construction favors earth and will undoubtedly continue to do so.

(3) Sites most adaptable to the construction of concrete dams have largely been exploited leaving only those locations where great quantities of material must be used in construction. For these reasons, it can safely be predicted that 75 percent of future construction will consist of earth- or rock-fill dams.

Full realization of the earth-dam potential is seriously handicapped by the lack of general design engineers who are experienced in the layout of earth-dam projects and soil mechanics engineers. Engineering students and practicing civil engineers are urged to study soil mechanics and to seek experience which will add to their knowledge of earth-dam design and construction in order that the present shortage and the anticipated demand in the future for experienced engineers in this field can be met.

(This article is based on the paper presented by Mr. Middlebrooks before a Soil Mechanics and Foundations Division Session presided over by R. F. Blanks, chairman of the Division's Executive Committee, at the Centennial Convention in Chicago.)

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Municipal refuse collection practice analyzed

Field investigations dealing with the problem of municipal refuse collection were conducted by the writers during 1950 and 1951 in 13 cities of California, as part of the activities of the University of California's Sanitary Engineering Research Project. The objectives of the investigation were to resolve the refuse collection operation into its component unit operations and to evaluate the magnitude of these operations, to study the physical characteristics of collection systems, and to develop methods of economic analysis and design of municipal refuse collection systems.

Results of work-method studies of more than 200 refuse collection trips are presented, and nomographic charts developed for determining labor requirements and fixed, operation, and maintenance costs of refuse collection. A rational method for estimating the cost of refuse collection is developed. Application of the nomographic method of economic analysis and design of refuse collection systems is illustrated by a sample design problem.

ERMAN A. PEARSON, A. M. ASCE, Assistant Professor of Sanitary Engineering

BRODERICK P. HASKELL, Jr., J. M. ASCE, Research Engineer, Sanitary Engineering Research Project

NORMAN B. JONES, Former Research Engineer, Sanitary Engineering Research Project, University of California, Berkeley, Calif.

Refuse collection and disposal is a significant problem in urban society, not only because of its physical magnitude, but also because the health, welfare, and esthetic character of a metropolitan area are intimately associated with the refuse removal operation. Increased urbanization and a general improvement in the standard of living have accentuated the problem as one of community responsibility.

Since the work of Hering and Greeley, *Collection and Disposal of Municipal Refuse*, published in 1921, little has been done to resolve the problem of refuse collection into its component operations and to develop a rational approach to the economic analysis and design of refuse collection systems. Most of the data reported by Hering and Greeley pertained to the collection of municipal refuse in horse-drawn wagons or carts, which were commonly employed at that time.

Because of the apparent need for basic engineering data regarding modern refuse collection and disposal practices, the Sanitary Engineering Research Project at the University of California at Berkeley, undertook a series of studies of the overall refuse problem. The principal objectives of this investigation were:

1. To study existing refuse collection practices and to resolve the manpower requirements into their component parts.
2. To evaluate the merit and economy of various collection practices, such as the size and type of the collection vehicle; the number of collectors per vehicle; the number of trips per day for a given haul distance; and the use of curb, alley, or rear-of-house pickup.
3. To obtain basic data necessary for the analysis and design of collection systems such as unit refuse production, labor requirements for various unit operations of collection, truck operation cost data, and characteristics of the haul operation.
4. To determine the interrelationships of many aspects of the overall problem, such as the effect of curb, alley, or rear-of-house collection on labor requirements; and the effect of haul mileage on haul speed.
5. To develop nomographs for the ready evaluation of labor costs of refuse collection, as well as the fixed, operation, and maintenance costs of refuse collection equipment.

Many of the data collected in this investigation necessarily apply only to California conditions; however, the general method of analysis of the unit operations of refuse collection, as well as the rational economic design of collection systems, are valid throughout the nation.

The Collection Operation

The collection operation, including the round-trip haul to the disposal site, constitutes the largest single portion of the total cost of the refuse activity. For purposes of review and analysis, it is generally convenient to classify the activity under three main divisions of collection, disposal, and administration. The cost of collec-

TABLE I. Unit Production of Combined Garbage and Refuse in 13 California Cities

Data Obtained July–September, 1950 and 1951

City	Number of Trips in Sample	Collection Frequency, Percent: Once per Week	Collection Frequency, Percent: Twice per Week	Residential Pickups, Percent of Total	Unit Production (Volume): Cu Yd per Service per Week	Unit Production (Volume): Cu Ft per Capita per Day	Unit Production, Pounds per: Service per Week	Unit Production, Pounds per: Capita per Day
Group I:*								
Berkeley	24	99	1	96	0.110	0.136	27.4	1.25
Fresno	35	60	35	84	0.110	0.120	34.1	1.52
Lodi	13	96	2	81	0.092	0.122	39.8	1.95
Oroville	10	65	18	76	0.089§	0.114§	34.0	1.62
Palo Alto	2	68	21	73	0.150	0.192	36.0	1.70
Sacramento†	12	68	25	69	0.060§	0.073§	23.0	1.03
Santa Rosa	12	93	6	82	0.079§	0.109§	32.0	1.63
Stockton	14	75	18	85	0.100	0.113	32.5	1.36
Avg., Gr. I	..	78	16	81	0.099	0.122	32.3	1.51
Group II:*								
Bakersfield	27	0	99	88	0.157§	0.189§	67.4	3.01
Riverside	23	0	99	89	0.111§	0.138§	41.3	1.90
Watsonville	23	0	93	91	0.087§	0.113§	32.3	1.55
Avg., Gr. II	..	0	97	89	0.118	0.147	47.0	2.15
Group III:‡								
Burbank	..	..	..	91	0.145	0.178	88.9	4.05
Long Beach	..	..	..	73	0.226	0.316	80.1	4.15
Avg., Gr. III	..	..	..	82	0.186	0.247	84.5	4.10

* Combined collection.
† Data collected during Dec. 1950—not significantly different from summer data.
‡ Separate collection: Garbage—twice per week, includes commercial swill.
Refuse and rubbish—once per week.
§ Mechanical packer.

tion averages approximately 84 percent of the total cost of the refuse activity in the 13 California cities included in this investigation, all of which employ some form of land disposal. It should be pointed out that one important reason for reviewing and analyzing the collection operation is that frequently economies can be

TABLE II. Unit Production of Commercial Refuse in Eight California Cities

Excluding Garbage and/or Commercial Swill

City	Unit Production: Cu Yd per Service per Week	Unit Production: Pounds per Service per Week
Bakersfield	0.60	252
Berkeley	1.19	240
Fresno	1.76	246
Riverside	2.04	343
Sacramento	0.90	339
Watsonville	2.63	358
Average	1.52	296
Burbank	0.57	162
Long Beach	0.53	86
Average	0.55	124
Average of total	1.28	253

effected in refuse collection practice which will amount to more than the cost of disposal by the sanitary landfill method.

Classification of Refuse. The classification of solid and semi-solid municipal wastes is fundamental to the design of a refuse collection and disposal system. The classification should be based on a suitable method of disposal determined by the economic, physical, and climatological characteristics of the area, and on a logical collection plan for the disposal method. For purposes of this investigation, the following classification has been adopted.

Refuse is the generic term which includes all solid and semi-solid municipal wastes. There are four principal subclassifications of refuse, which are:

1. *Garbage.* The solid or semi-solid waste material resulting from the preparation and consumption of foodstuffs. The term *commercial swill* refers to that portion of this material which is produced by restaurants, cafeterias, boarding houses, etc., and which may be of suitable quality for use as animal food.

2. *Domestic or Residential Refuse.* The heterogeneous mixture of waste material from the household, including such material as rags, bottles, tin cans, clothing, cartons, and papers.

3. *Commercial Refuse.* The heterogeneous mixture of waste material from commercial or business establishments, including such material as rags, bottles, tin cans, wooden boxes and crates, cartons, and varying amounts of cardboard, packing, and paper, which may be subject to separate collection.

4. *Rubbish.* Large and bulky waste material such as tree and yard trimmings, old furniture, building or concrete debris, children's large toys, rubber tires, etc., which does not lend itself to regularly scheduled collection. Ashes, which might be included as rubbish, do not constitute a significant proportion of refuse in California.

Some classifications of refuse subclassify the material as combustible or non-combustible. Since most cities in California use some form of land disposal and employ combined collection of garbage and residential refuse, it is of little value to make any distinction as to the combustible nature of the refuse. Similarly, the distinction between what may be called "domestic" or "commercial" refuse and "rubbish" (subject to special collection) may be based on the quantity involved rather than on the character of the material. For example, in some cities, combined garbage and domestic refuse, the latter including small amounts of grass cuttings or yard trimmings, is accepted by the collection agency, but the placing of yard trimmings in the container in sufficient amounts to constitute the major portion of its content is prohibited. Large amounts of yard trimmings are, therefore, classified as rubbish and as such are subject to special collection, for which a supplemental fee is generally charged.

Field Investigations. The literature in the field of refuse collection and disposal is replete with unit cost figures which, though they may illustrate the magnitude of the problem in a given area, are not suitable for use in comparing the relative efficiency and economy of operation of two different systems. Many influencing factors, often virtually impossible to evaluate without work-methods studies, must be considered when interpreting cost figures.

Field investigations were conducted during the summer months of 1950 and 1951. Field personnel consisted of two teams of two men each, who were assigned to refuse collection vehicles for the purpose of recording all data pertinent to the collection operation. In addition, one field in-

vestigator was placed at the disposal site to record data such as the number of cubic yards delivered, time use of equipment, and general operational procedures there.

The field personnel accompanying the collection crews recorded the quantity of refuse collected, the number, type, and location of containers, and the time required to perform the individual activities comprising refuse collection. The pickup operation was divided into time on the truck, and time spent by the collector on private property, in walking on the street, at the refuse container while transferring its contents to a transfer can, in the actual loading operation, in waiting, and in resting.

One member of the field crew on the collection vehicle followed one refuse collector for a period of 10 to 15 minutes, then changed to another collector for a similar period, observing the time required for each operation by means of a stop watch. It was thus possible to evaluate quantitatively the activities of a "composite" collector without timing each individual continuously. Such work-method studies permit the resolution of the labor requirements of refuse collection into units of man-minutes per ton of refuse collected.

Unit Operations. The collection operation may be subdivided into the four unit operations of pickup, haul, off route, and at disposal site. *Pickup* includes the time consumed during the actual collection of refuse from the premises, and consists of the net working time from the pickup of the first container until the last container of refuse is loaded on the collection vehicle. *Haul* designates the time required for the round trip to the disposal site and is measured from the time of pickup of the last container on the collection route until the collection vehicle returns to the first container of the succeeding route, excluding the time spent unloading or waiting at the disposal site. *Off-route* time includes such activities as organized rest periods; time out for smoking, eating, refreshments, personal reasons, contacting residents and supervisors; and other miscellaneous activities not devoted to the other three operations but which entail group participation on the part of the entire collection crew. It does not include a formal lunch period. *At site* includes the time spent unloading, and waiting to unload, the refuse at the disposal site.

Refuse Production. Table I reports the unit production of combined garbage and refuse in the 13 California cities investigated in this study, grouped according to frequency and type of collection (combined or separate). It shows that the average unit production of refuse in eight California cities employing primarily once-per-week combined collection (Group I) was 32.3 lb per service per week. The two cities in Group III, employing separate collection of garbage (including commerical swill), and refuse and rubbish, with twice-per-week collection of garbage and once-per-week collection for the remainder, had an average total refuse production of 84.5 lb per service per week. The difference in refuse production may be attributed to differences in the extent of collection service rendered. The production figures reported for Group III, Burbank and Long Beach, include the commercial swill contribution, whereas all other cities exclude commercial swill.

Table II reports a summary of the unit production of commercial refuse in eight California cities. The average of six cities employing combined collection but excluding commercial swill was 296 lb per service per week, whereas the average for Burbank and Long Beach, employing separate collection of commercial refuse and rubbish, was only 124 lb per service per week. A partial explanation of the difference in production may be that in combined refuse collection systems employing separate commercial swill collection, considerable amounts of commercial swill are included with the commercial refuse. Commercial refuse was usually collected six times per week.

TABLE III. Average Labor Requirements for Pickup Operation, Man-Minutes per Ton of Combined* Refuse Collected, for 13 California Cities

City	Population	Year	Number of Men per Collection Vehicle	Residential Pickups, Percent of Total†	Rear-of-House Pickups, Percent of Total†,‡	Tons per Trip	Pickup Time, Man-Minutes per Ton
Bakersfield	42,000	1951	3	87	26	2.62	158
Berkeley	113,217	1950	3	85	90	1.60	123
		1951	3	99	100	2.08	138
Burbank:	78,313	1950					
Garbage			3	95	0	2.99	153
Refuse			3	87	0	3.32	104
Fresno	90,618	1950	2	82	32	2.06	126
		1951	2	90	41	1.97	117
Lodi	13,727	1950	2.6§	73	46	3.78	124
		1951	3	84	62	4.34	141
Long Beach:	244,072	1950					
Garbage			2	96	0	1.45	107
Refuse			2	66	0	1.63	96
Oroville	5,460	1951	3	76	53	1.83	291
Palo Alto	25,290	1950	2.6§	82	91	1.90	158
Riverside	46,399	1950	2.3§	83	83	2.16	160
		1951	2.5§	96	71	2.46	167
Sacramento	135,761	1950	2.7§	69	71	2.70	157
Santa Rosa	17,905	1950	2	82	85	2.15	155
Stockton	71,660	1950	3.3‖	72	83	3.54	194
		1951	3	90	94	2.73	171
Watsonville	11,516	1950	2.4	45	..	2.34	111
		1951	2	99	87	2.19	165
Average¶			2.6	82	74.3	2.47	148

* Unless otherwise noted.
† Percent of trips sampled—not necessarily representative of average for entire city.
‡ Remainder are either curb or alley or both.
§ Some 2 men, some 3 men.
‖ Some 3 men, some 4 men.
¶ Excluding Burbank, Oroville, and Long Beach.

Labor Requirements. Table III reports the labor requirements for the pickup operation in the combined collection of garbage, residential, and commercial refuse in eleven California cities, as well as in Burbank and Long Beach where separate collection is practiced. The average pickup time for ten cities excluding Burbank, Long Beach, and Oroville, was 148 man-minutes per ton with a standard deviation of the mean of 23 man-minutes. The average pickup time for the 198 individual refuse collection trips was also 148 man-minutes per ton, with a standard deviation of only 39 man-minutes per ton. In spite of the numerous variables which affect pickup time, such as container location (at rear of house or curb), service density, collection frequency, and type of collection vehicle, a nor-

mal distribution and relatively minor range in the field data are to be noted.

The labor requirements for the pickup of commercial refuse in seven California cities are listed in Table IV. The average pickup time of 136 man-minutes per ton for commercial refuse in the cities listed is only slightly less than the 148 man-minutes per ton average for the pickup of combined garbage and domestic refuse.

The time devoted to the pickup operation averaged 70 percent of the total trip time for the eleven cities investigated, with a standard deviation of the city averages of only 4.4 percent.

Container Location. The effect of the container location on the pickup time is shown in Fig. 1. The curve represents the statistical line of best fit—or trend line—of the field data. The pickup time varies from approximately 103 man-minutes per ton where all containers were at alley or curb, to 165 man-minutes per ton where all containers were at rear of house. The effect of container location on the cost of collection can be readily computed by using the pickup time-unit and the prevailing wage rate. For example, assuming an average wage rate of $1.50 per hour (2.5 cents per man-minute) and employing the trend line in Fig. 1, the cost of labor for pickup of refuse at the curb or alley is approximately $2.56 per ton, whereas for 100 percent rear-of-the-house pickup it is $4.15 per ton. The difference in cost of rear-of-house or curb and alley refuse collection is approximately $1.59 per ton.

The data presented in Fig. 1 illustrate why a comparison of two different collection systems should not be made without a careful study of influencing factors. It is apparent that two cities with comparable conditions for all factors, such as wage rates, haul distance, and type of collection equipment, except the one of container location, may have widely varying unit costs.

Pickup Density. Although the field investigation did not specifically study the labor requirements of rural refuse collection, it is possible to analyze the effect of population or pickup density on the pickup requirements. Figure 2 reports the relationship between pickup time in man-minutes per ton (percentage of city average) and the average pickup density in services per route mile. In preparing this figure, collection trips within a range of pickup density of 10 services per mile were grouped together. The figure indicates that pickup densities between 30 and 180 services per mile have relatively little effect on the labor requirements of the pickup operation. However, at pickup densities less than 30 services per mile, the labor requirement increases markedly.

Type of Collection Vehicle. A comparative analysis of the efficiency of mechanical compaction-type collection vehicles and open-body trucks in the pickup of combined refuse is given in Table V. It would appear that the open-body truck is somewhat more efficient from the standpoint of labor requirements of the pickup operation. However, the average number of containers per service was slightly greater for the mechanical-packer truck group than

TABLE IV.

Average Labor Requirements for Pickup of Commercial Refuse, for Seven California Cities

City	Year	Number of Men per Collection Vehicle	Commercial Pickups, Percent of Total*	Curb or Alley Pickups, Percent of Total*,†	Tons per Trip	Pickup Time, Man-Minutes per Ton
Bakersfield	1951	3	87	86	2.52	160
Burbank‡	1950	3	100	100	2.13	127
Fresno	1950	4	100	90	3.32	125
Long Beach‡	1950	2	98	100	1.27	112
Riverside	1950	2	100	100	1.79	184
Sacramento	1950	3 & 2	92	64	2.57	137
Watsonville	1950	2	93	100	1.70	115
Average		2.6	96	90	2.19	136

* Percentage of trips sampled—not necessarily representative of average for entire city.
† Remainder are pickups from the street—with container at rear of premises.
‡ Refuse and rubbish.

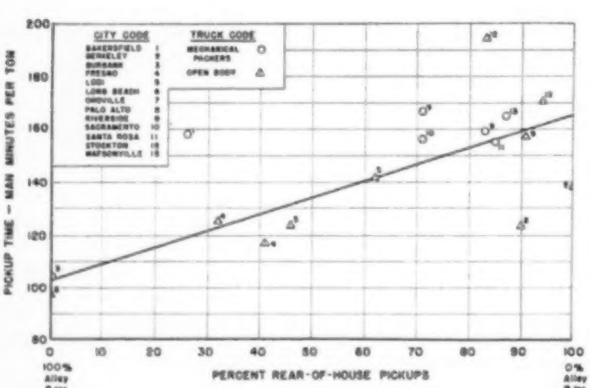


FIG. 1. Location of refuse container, at rear or front of house, affects pickup time and cost.

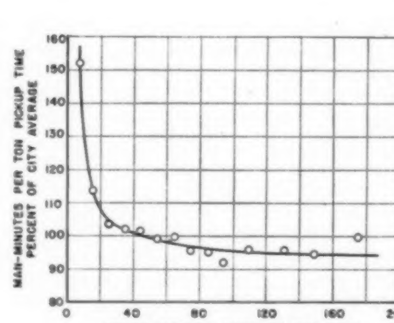


FIG. 2. Pickup labor, per ton of refuse collected, increases rapidly on sparsely settled routes, that is, on routes with less than 30 services per mile.

TABLE V.

Comparative Analysis of Efficiency of Mechanical Packers and Open-Body Trucks in Refuse Pickup Operation

Average of Field Data from Nine California Cities, 1950–1951

Type of Truck	Total Number of Trips	Number of Men per Truck	Percent Rear-of-House Pickups	Percent Residential Pickups	Pickup Density: Services per Mile	Pickup Density: Containers per Mile	Pickup Only—Man-Minutes: Per Ton	Pickup Only—Man-Minutes: Per Yard	Pickup Only—Man-Minutes: Per Service	Pickup Only—Man-Minutes: Per Container	Unit Weight of Refuse, Lb per Cu Yd
Mechanical packers. .	97*	2.7	65.8	88.6	76	103	159	34.2	2.24	1.59	440
Open-body trucks . .	87†	2.5	65.4	87.2	69	70	135	21.4	1.84	1.73	323

* Data from Bakersfield, Lodi, Riverside, Sacramento, Santa Rosa, and Watsonville.
† Data from Berkeley, Fresno, Lodi, Riverside, and Stockton.

TABLE VI. Where Pickup Time Is Spent with Mechanical Packers and Open-Body Refuse Collection Trucks

Average of Field Data from Nine California Cities, 1950–1951

Type of Truck	Characteristics of Group	Pickup Time, Man-Minutes per Ton	Percent of Pickup Time Spent: On Truck	On Street	On Property	At Can	Loading	Waiting	Resting	Pickup Time, Percent of Total Trip
Mechanical packers. . . .	Same as Table V	159	21.2	18.1	19.9	16.5	12.8	7.0	4.4	71.7
Open-body trucks	Same as Table V	135	25.9	18.8	21.0	14.7	13.2	1.9	4.5	68.6

for the open-body trucks. Thus, a portion of the increased pickup time for the mechanical packers should be attributed to the handling of a greater number of containers per service.

Ninety-seven collection trips with mechanical packers reported an average unit weight of refuse of 440 lb per cu yd, whereas the average unit weight of 87 collection trips with open-body trucks was 323 lb per cu yd, giving an average compaction ratio of approximately 1.36 to 1.0.

Results of the time studies on the activities of the refuse pickup operation are reported in Table VI. The data are grouped with respect to the type of collection vehicle, each group having the same characteristics as reported in Table V. For essentially the same physical characteristics of pickup for each group, the division of time for the pickup operation is comparable for all components of pickup except the time spent "on truck" and "waiting." The open-body truck group may require more "time on truck" owing to the slightly lower pickup density and the occasional need for a collector to work on the truck while assisting in the loading operation. Considerably more time is classified as "waiting" for the mechanical-compaction-truck group than for open-body trucks—a significant portion of which may be attributed to the operation of the compaction equipment.

Equipment Requirements. The relationship between the total capacity of the collection vehicles in daily use and the number of services in 11 California cities investigated is shown in Fig. 3.

There appears to be no significant difference in the equipment requirements for the collection of combined refuse with open-body trucks or with mechanical compaction-type vehicles. This finding may be partially explained by the general failure to utilize compaction-type collection vehicles to capacity in the cities investigated in the study.

Haul Speed. The relationship between the total haul distance and the average haul speed, as observed in the 13 cities studied, is shown in Fig. 4. Haul distances ranged from 5.8 to approximately 22 miles, with a maximum average haul speed of 27 miles per hour for the 22-mile haul distance. The majority of cities with

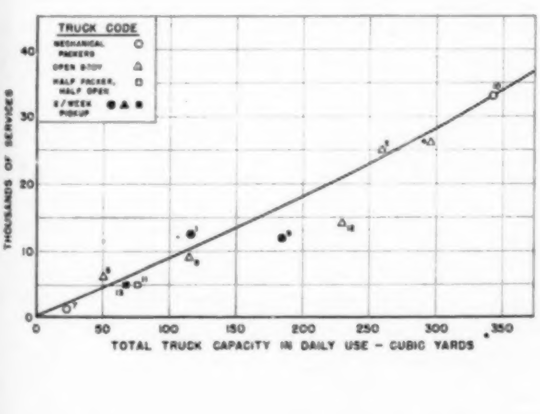


FIG. 3. Total capacity of garbage and refuse trucks in daily use in 11 California cities is related to number of services handled.

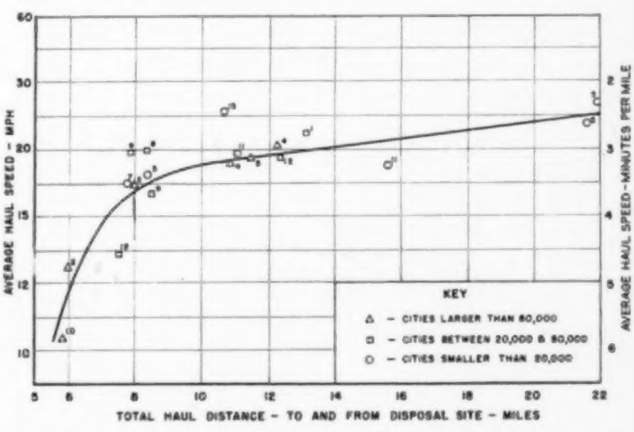


FIG. 4. Haul speed for refuse trucks increases with round-trip distance to disposal point from center of city (assumed pickup point).

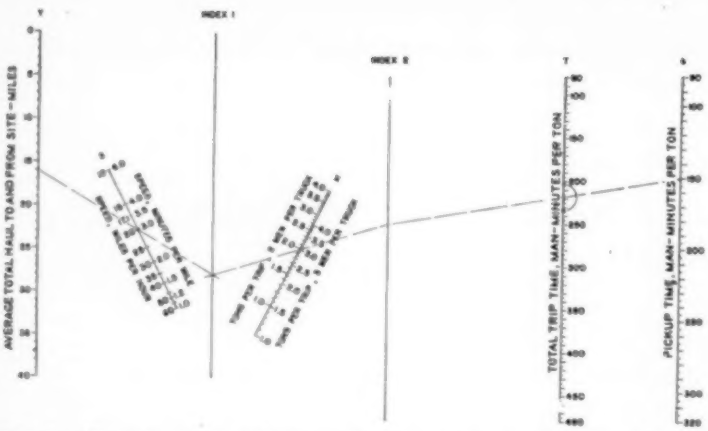


FIG. 5. Chart for analysis of refuse collection systems, to determine manpower requirements in man-minutes per ton. Chart includes 15 min off route, and 5 min at disposal site, per trip. Read chart in three steps:

1. Place straight edge through "Average Total Haul" on Y and "Speed" on S. Extend to Index 1 and mark point.
2. Place straight edge through point on Index 1 and "Tons per Trip" on X for either 2 men or 3 men per trip, whichever applies. Extend to Index 2 and mark point.
3. Place straight edge through point on Index 2 and "Pickup Time" on b. Read "Total Trip Time" on T.

haul distances of 8 to 16 miles indicated average haul speeds of 15 to 20 miles per hour.

Rational Design of Collection Systems

Labor Requirements. Unit operations of pickup, haul, off route, and at site can be resolved into an expression for the labor requirements of the refuse collection operation. The equations may be developed for purposes of analysis or design, and nomographic charts based on these equations may be constructed to provide a rapid, accurate solution to many of the practical problems encountered.

For purposes of analysis or control of a system, an equation of the form,

$$L = b + \frac{ade}{c} + \frac{20a}{c} \quad . \; . \; (1)$$

may be used, for which, in the absence of standard symbols, the following letter symbols have been adopted:

L = man-minutes per ton for total trip
a = number of collectors per vehicle
b = pickup time, man-minutes per ton
c = average tons of refuse per trip
d = round-trip haul distance, miles
e = average haul speed, minutes per mile
$\frac{20a}{c}$ = off-route and at-site man-minutes per ton (allowing 15 minutes off route and 5 minutes at site per trip).

Figure 5 is a nomographic expression of Eq. 1. Employing estimates or results of field observations for the pickup time, average haul speed and tons per trip, and knowing the average haul distance and number of trips per day, the nomograph is employed to solve for the total labor requirement in man-minutes per ton. It is simple to compare the computed value with the actual value based on the tons of refuse collected during a given period, the number of men employed, and the length of the work day. Thus, it is possible to determine the relative efficiency of a refuse collection system. The constants of 15 minutes for off route and 5 minutes at the disposal site per trip are based on the results of the field studies. Other constants may be employed to fit local situations.

An equation similar to Eq. 1 may be developed for the design of refuse collection systems:

$$\frac{480a}{g} = bc + ade + 20a \quad . \; . \; (2)$$

in which, g = total number of trips per day, and other terms are as defined in Eq. 1. The term $480a/g$ is equal to the man-minutes per trip based on an 8-hour (480-min) day. Equation 2 can be simplified and rewritten as

$$\frac{480}{g} = \frac{bc}{a} + de + 20 \quad . \; . \; (3)$$

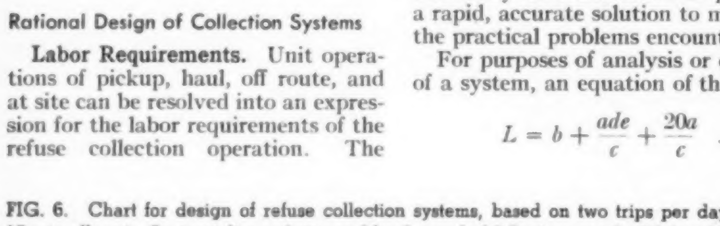
Nomographic expressions of Eq. 3 are presented in Figs. 6 through 8. For purposes of simplicity the nomographic charts have been prepared for two haul speeds, 17.1 and 20 mph (3.5 and 3.0 min per mile) and for two and three collection trips per day.

Fixed, Operation, and Maintenance Costs. The previous nomographs have been concerned with the labor requirements of refuse collection. It is also possible to express the fixed, operation, and maintenance costs in an equation,

$$F = \frac{h}{cks}\left[1 + \frac{i(s+1)}{2}\right] + \frac{oy}{c} \quad . \; (4)$$

FIG. 6. Chart for design of refuse collection systems, based on two trips per day, 15 min off route, 5 min at disposal site, and haul speed of 3.5 min per mile (17.1 mph). Read chart in two steps:

1. Using straight edge, line up known value of "Pickup Time" on center scale with known value with respect to number of men per truck.
2. Extend to read unknown value on third scale for same number of men per truck.



in which

F = total operating (fixed, operation, and maintenance) cost in dollars per ton

h = initial cost of collection vehicle, dollars

i = interest rate on capital

k = average number of trips per year per truck

s = amortization period for collection vehicle, usually useful life of vehicle

o = operation and maintenance cost per mile per truck, dollars

y = average total mileage per trip, pickup plus haul

Equation 4 is based upon straight-line depreciation and average annual interest. The economic analysis is made on the basis of a single truck. Figure 9 is a nomographic chart for the determination of fixed, operation, and maintenance costs based on Eq. 4, a useful truck life of 10 and 15 years, and interest rate of 4 percent. [A similar nomograph employing 6 years for useful life of collection vehicle at interest rates of 4 and 5 percent has been prepared by the authors.]

Employing the nomographs for the determination of the labor requirement and the fixed, operation, and maintenance costs, it is possible to design the most economical refuse collection system and estimate the unit cost of collection for a given set of conditions. With the addition of the costs of disposal and administration, the total cost of the refuse activity can be estimated with a high degree of accuracy. Similarly it is possible to evaluate the cost of collection and haul to alternate disposal sites, as well as to review the economy of various types of collection vehicles or methods of operation.

Illustrative Example. The following example of the economic design of a refuse collection system illustrates the use of the nomographic charts presented as Figs. 6 through 9.

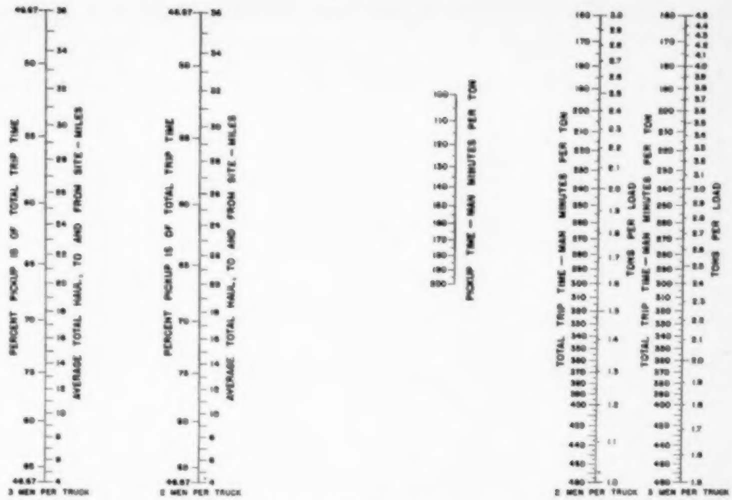


FIG. 7. Chart for design of refuse collection systems, based on two trips per day, 15 min off route, 5 min at disposal site, and haul speed of 3 min per mile (20 mph). Use scales to obtain values in manner described for Fig. 6

Community Characteristics

Population: 45,000

Services: 12,000 residential
600 commercial

Container location: 50 percent rear of house, 50 percent curb or alley

Collection frequency: Twice per week collection of combined garbage and refuse. Commercial swill collected by contractor at no cost to city or producer.

Disposal: Suitable location for municipal incinerator, 2 miles from geographical center of city (4-mile total haul). Estimated total cost of incineration, \$2.15 per ton. Estimated cost of disposal by sanitary land fill, \$0.66 per ton.

Design Factors (Estimated or determined by field study)

Pickup labor requirements: 140 man-minutes per ton (Fig. 1) city average, based on 50 percent rear-of-house collection (50 percent curb or alley).

Refuse production: Residential, 48 lb per service per week, assuming 20 percent of commercial services included in this figure as neighborhood business. Commercial, 250 lb per service per week in downtown commercial area (Table II).

Type of collection vehicle: Mechanical packers used throughout.

Service density: 90 services per mile.

Problem

1. To determine the most economical collection system with respect to size of vehicles, number of trips per day, and number of collectors per truck.

2. To estimate the total cost of refuse collection and disposal employing incineration.

3. To determine how far the refuse

FIG. 8. Chart for design of refuse collection systems, based on three trips per day, 15 min off route, 5 min at disposal site, and haul speed of 3 min per mile (20 mph). Use scales to obtain values in steps as described for Fig. 6.

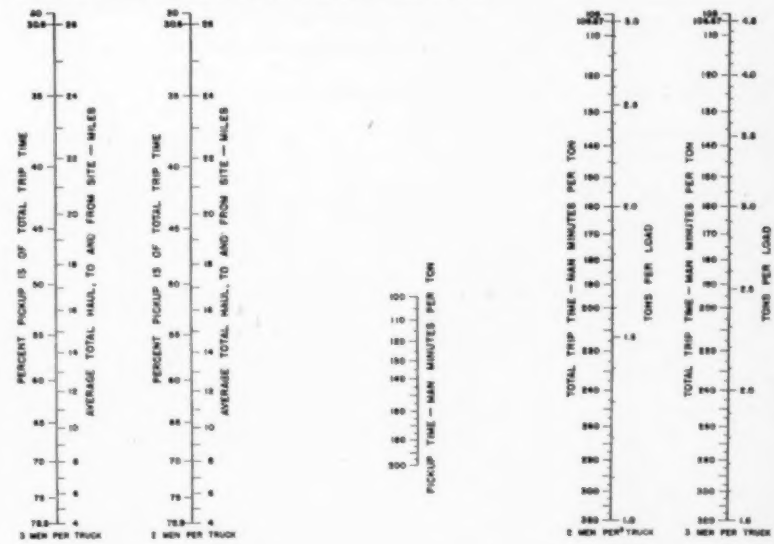


TABLE VII. Economic Comparison of Refuse Collection Systems

Disposal by Incineration

System	Tons per Load (Trip)	Cost, Dollars per Ton: Collection and Haul Labor*	Fixed, Operation, and Maintenance† (Collection Equipment)	Disposal‡ (All Costs)	Total
3 trips per day:					
3 men per truck . . .	2.70	4.45	0.81	2.15	7.41
2 men per truck . . .	1.80	4.45	1.20	2.15	7.80
2 trips per day:					
3 men per truck . . .	4.41	4.07	0.62	2.15	6.84
2 men per truck . . .	2.95	4.07	0.92	2.15	7.14

* Based on: 140 man-min per ton average pickup time; \$0.025 per man-min (\$1.50 per hour); 15 min per trip off route; 5 min per trip at site; 3.5 min per mile (17.1 mph) average haul speed; 4 miles round-trip haul.

† Based on: initial cost packer-body truck, \$8,000.00; \$0.16 per mile operation and maintenance costs; 4 miles average round-trip haul plus average of 3 miles per pickup route; 10-year truck-life; 4 percent average annual interest; straight-line depreciation; 312 working days per year per truck.

‡ Based on: initial cost of incinerator, \$2,000.00 per rated ton of capacity; \$2.00 per ton operation and maintenance costs ("Municipal Incineration," *Technical Bulletin No. 5*, Sanitary Engineering Research Project, University of California, June 1951); 20-year amortization period; 4 percent average annual interest. Assume cities own land at site for incinerator.

can be hauled to a trench-fill disposal site at a total cost not to exceed that for collection and disposal employing incineration.

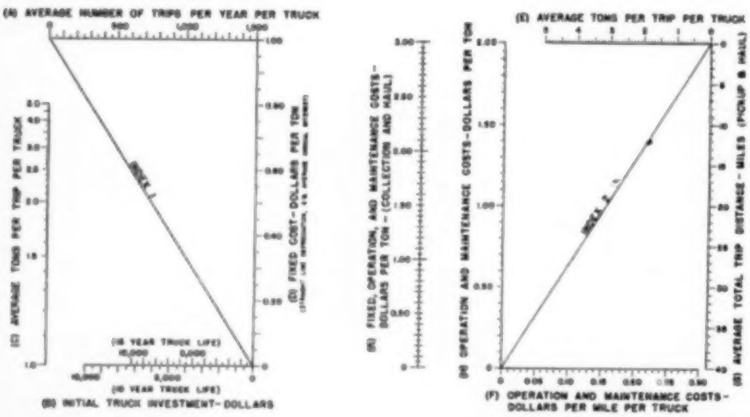
4. To estimate equipment and manpower requirements for the system.

Design

The determination of the most economical combination of size of collection vehicle, number of trips per day, and number of men per truck involves an economic comparison of the different systems. Employing Figs. 6 and 8, a pickup time of 140 man-minutes per ton, an average round trip haul of 4 miles, and an average haul speed of 17.1 mph, the total trip time and tons of refuse collected per trip may be determined for the four possible systems reported in Table VII.

FIG. 9. Chart for determination of fixed, operation, and maintenance costs of refuse collection, in dollars per ton. Truck life may be assumed to be either 10 or 15 years, and interest rate, 4 percent. Read chart in four steps:

1. Place straight edge through appropriate values on lines A and B. Mark intersection on Index 1.
2. Place straight edge through point on Index 1 and value of "Average Tons" on C. Extend to "Fixed Cost" on D.
3. Similarly, obtain point on H, "Operation and Maintenance Cost," using E and F, Index 2, and G.
4. Connect values on D and H. Read value desired on K.



Knowing the tons of refuse per trip and assuming cost factors in accordance with the footnotes to this table, the fixed, operation, and maintenance costs per ton can be determined.

Table VII, which reports the costs of collection and disposal by incineration for the four possible systems, indicates that two trips per day and three men per truck is the most economical combination. In order to effect such a cost, however, it is necessary to collect 4.41 tons of refuse per trip, which requires a rather large collection vehicle. The second most economical system is the two trips per day, two men per truck combination, at a total cost of \$7.14 per ton.

To determine how far combined refuse may be hauled to a trench-fill disposal site, the estimated cost per ton for disposal by the trench-fill method (\$0.66) is subtracted from \$7.14 per ton for the system employing incineration. The difference, \$6.48, is the allowable cost per ton for the labor and fixed, operation, and maintenance costs of the longer-haul system.

The determination of the length of haul, such that the total cost of collection is equal to \$6.48 per ton, involves also an economic comparison of the possible combinations. It is apparent that the most probable combinations will be two trips per day with either two or three collectors per truck. Employing Fig. 7, a round-trip haul distance of 14.5 miles is found to be possible with two trips per day, two collectors per truck, and 2.52 tons of refuse per trip.

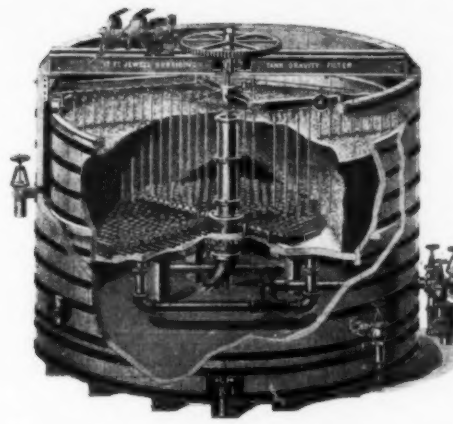
Similarly, it is found that a round-trip haul distance of slightly over 18 miles is possible with two trips per day, three collectors per truck, and an average of 3.55 tons of refuse per trip. Thus a trench-fill location slightly more than 9 miles from the geographic center of the city (assumed as the point of collection for all routes) could be used at a cost equal to that employing incineration for disposal.

Having adopted the two trips per day, three men per truck collection system in conjunction with trench-fill disposal, it is relatively easy to lay out the remainder of the collection system.

Each truck must haul, on the average, $2 \times 3.55 = 7.10$ tons of refuse per day in two trips. With a unit production of 48 lb of refuse per week for twice-per-week collection, each truck will be able to handle $\frac{7.10 \times 2{,}000}{24} = 590$ services per day, or 295 services per trip. Based on an average pickup density of 90 services per mile, the mileage during pickup is found to be 3.28 miles, only slightly greater than initially estimated.

Since one vehicle can collect 590

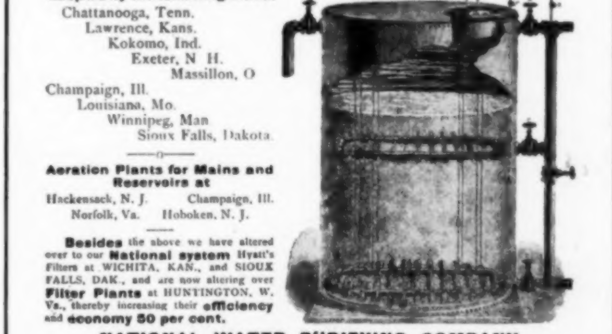
(*Continued on page 258*)



Tank filter of more advanced type was advertised in *The Manual of American Water-Works, 1897,* by The O. H. Jewell Filter Co., Chicago, and The Morrison-Jewell Filtration Co., Philadelphia. Ad claimed that this Jewell filter was "the acknowledged standard of mechanical filtration."

Outstanding achievements in water supply and treatment

HARRY E. JORDAN, Aff. ASCE, Secretary, American Water Works Association, New York, N.Y



Typical of early high-rate types was filter advertised in *The Manual of American Water-Works, 1888.* Ad made interesting claim regarding equipment of rival, Hyatt Pure Water Co., whose ad appeared on facing page. High-rate filter was one of purely American contributions to field of water purification.

Midway through the nineteenth century, 68 cities in the United States and 6 in Canada had developed public water supply systems. Contrary to common assumption, the greatest number of these (30) were not in New England but in the Middle Atlantic States. While Boston, Mass., traditionally is credited with the first public major supply in the United States (1652), it was not until 1848 that the present system was started. New York, N.Y., began its first limited supply and distribution system in 1744, but not until 1835 was a substantial distribution system installed.

The first pumped supply in the United States was built in Bethlehem, Pa., in 1754. To quote from M. N. Baker's first *Manual of American Water-Works, 1888:*

> Water was taken from a spring issuing from magnesian limestone. It was conducted 350 ft through an underground conduit to a cistern, or well, whence it was raised by a 5-in. lignum vitæ pump, through bored hemlock logs, to a wooden tank in the village square, 70 ft above the pump. There being trouble from the bursting of the wooden pipes, $1^1/_4$-in. pipes of sheet lead were tried. They were soldered along the edges and bedded in a cement of pitch and brick dust, and laid in a gutter of brick. This expedient did not prove very successful.

Among the older works of larger cities are those of Providence, R.I. (1772), Worcester, Mass. (1798), Philadelphia, Pa. (1801), Baltimore, Md. (1807), Albany, N.Y. (1813), Reading, Pa. (1819), Pittsburgh, Pa. (1820), Cincinnati, Ohio (1820), Richmond, Va. (1820), Detroit, Mich. (1827), St. Louis, Mo. (1830), and Chicago, Ill. (1840). Buffalo, N.Y., did not start its supply until 1852; Washington, D.C., until 1853; Cleveland, Ohio, until 1854; Denver, Colo., and Indianapolis, Ind., until 1871; Milwaukee, Wis., until 1872; and Kansas City, Mo., until 1873.

Springs and dug wells were the favorite sources of supply for the early engineers. Lakes or ponds were appropriated by fortunately located communities. But as time went on and the cities grew, need for more water led to the introduction of surface water from nearby streams.

Albert Stein built a sand filter for Richmond in 1832 which was hardly complete before its failure was ob-

vious. At Elizabeth, N.J., when the works were built in 1854, a sand-and-charcoal filter was installed, which was still operating in 1889 when the *Manual of American Water Works* was compiled by M. N. Baker.

Because of the growing realization of the deficiencies in sanitary quality of supplies in 1865 the Water Commissioners of the City of St. Louis employed James P. Kirkwood, Past-President, ASCE, to travel in England and Europe and to recommend, on the basis of his studies, water treatment works for that city. His report, published in 1869, displayed great admiration for the works built by James Simpson and contemporary engineers in England, and recommended settling and slow sand filtration (on the British model) for installation at St. Louis. However, somewhat pathetically, Mr. Kirkwood observed in a note written in April 1869, that "the public mind of St. Louis does not yet seem to consider filtration important."

A peculiar by-product of the St. Louis project was that Mr. Kirkwood's design of the settling basin and slow sand filters made for St. Louis was modified and used by him for the works at Poughkeepsie, N.Y., first operated in 1873. This system was initially developed in its complete form from the source (the Hudson River) through pumps, filters, distribution reservoir, and mains. The Poughkeepsie filtration system was the first one in the United States to follow accepted British designs and experience. Although substantial additions in structures and changes in methods have been made in the intervening 80 years, the filters still are operating and the water supply is acceptable. This supply, it should be noted, is taken from the Hudson River at a point below the location recommended in 1951 by the Engineering Panel (Thorndike Saville, W. W. Horner, L. R. Howson, and Abel Wolman, all Members, ASCE) for abstracting water for a rapid sand filtration plant to augment New York City's upland sources.

Shortly after Mr. Kirkwood had completed the Poughkeepsie plant, J. W. Hyatt, I. S. Hyatt, and Patrick Clark developed the units which were the forerunners of the modern rapid sand filters. The first patents were granted in 1881, and by 1889 the Hyatt Company held 59 separate patents for design, treatment materials, and methods, etc. A dozen or more separate companies competed in designing and installing water treatment systems. The business was cruelly competitive. For example, one company advertised how many plants built by the Hyatts had failed and had been rebuilt by the advertiser. Although competition made for progress, one by one, the various companies had financial difficulties and were liquidated or consolidated with others. Today there are such organizations as the Builders Iron Foundry, the Permutit Co., the Roberts Filter Co., the American Water Softener Co. and the International Filter Co. which, among others, carry on the commercial development and sale of rapid sand filter equipment.

In 1895, Allen Hazen, M. ASCE, after a tour of European water works, wrote *The Filtration of Public Water Supplies*, which was authoritative in content and was widely read by those who were then attempting to improve water supply quality in the United States. Mr. Hazen was one of that galaxy of great engineers—George W. Fuller, Paul Hansen, G. C. Whipple, H. W. Streeter, and Robert S. Weston, all Members, ASCE—who were inspired by the brilliant leadership of William T. Sedgwick to strike out into the new fields of environmental sanitation. Few university professors have contributed as much as did Mr. Sedgwick through the work done by those whose genius he fostered.

At the turn of the century, Messrs. Fuller, Hazen, and Weston led the way in conducting experimental studies of the various filtration systems for cities where water treatment was needed. In 1895–1896 Mr. Fuller conducted objective and parallel tests of three of the competitive rapid sand filters for the Louisville (Ky.) Water Co. These studies demonstrated the need for the settling of coagulated particles from the water before filtration. Neither the Hyatts' 1883 patent on the use of alum as a coagulant nor patents later issued to competitors had indicated knowledge of this important fact. In the modern rapid sand filtration plant, from 75 to 90 percent of the suspended material is removed from the water before it enters the filters. With predisinfection of the water, little bacterial removal is required of the filter layer.

The treatment plant built by local engineers of the Louisville Water Co. (after Mr. Fuller had completed his studies and moved on to similar work at Cincinnati and with Mr. Weston at New Orleans, La.) embodied some of the recommended features, but failed to consider certain hydraulic requirements necessary for successful operation. However, at Little Falls, N.J., in 1902, the Fuller designs were built into operating structures. The round filter with the revolving rakes gave way to the rectangular unit with a higher wash-water flow rate.

The modern rapid sand filtration plant emerged. Today's great installations such as those at Chicago, Cleveland, Detroit, Milwaukee, and Toronto are the descendants of the little wooden tubs built by Messrs. Hyatt, Clark, Jewell, and others and welded into new form and efficiency by Messrs. Fuller, Hazen, Weston, Joseph W. Ellms, all Members of ASCE, and their contemporaries.

Alum as a Coagulant

About 1900, when several large cities were considering filtration of public supplies to reduce the typhoid death rate, the U.S. Engineer Corps assigned A. M. Miller, M. ASCE, to conduct experimental studies of filtration at Washington, D.C. (The supply works of that city were then and still are under the control of the Army Engineers.) Colonel Miller's report recommended that rapid sand filters be installed.

Objections were made by various persons, including representatives of the District of Columbia Medical Society. When the authorization for building the water treatment plant was before Congress, the Senate Committee on District Affairs held hearings. The record of the hearings was published ("Purification of the Washington Water Supply," Committee Hearings, U.S. Senate, U.S. Government Printing Office, Washington, D.C., 1903). Testimony by Rudolph Hering, M. ASCE, and by Messrs. Fuller, Weston, and others favored the installation of rapid sand filters, and the use of alum as a coagulant.

A report was made by a special committee of the Medical Society of the District of Columbia which favored slow sand filters. Under the subheading, "Addition of Alum to Potomac Water Not Warranted," the committee stated (in part):

> An important consideration with reference to the use of mechanical (rapid sand) filters arises in connection with the effect of the chemical used as a coagulant on the health of the consumers of the filtered water.
>
> Mr. Weston's statement that "The almost unanimous conclusion is that, if the alkalinity of the raw water is sufficient to decompose completely the applied chemical, its use is in no way prejudicial to health" has certainly not been proved by the experience of the medical profession and (as stated by Mr. Weston, at least) is incorrect. Everything will depend upon the nature of the substances into which the "applied chemical" is decomposed.
>
> The most that can be said is that it has *not yet been demonstrated* that the alum as

used in mechanical filters is prejudicial to health. In the opinion of this Committee the people of this community should not be made use of to determine that question.

After the hearings were completed, the installation of slow sand filters was approved. The MacMillan filter plant was built and provided with a settling basin to preclarify the Potomac River water. But in less than five years the operation of the settling basin and filters proved unsatisfactory. It was then decided to install a coagulating system (using alum) to assist the settling basin in preparing the water for the slow filters. The coagulant is still used; the filters still operate; the doctors who opposed alum as a coagulant have gone to their reward; and the residents of the District of Columbia as well as the many thousands in other cities who use water coagulated with alum before filtration have demonstrated no ill health attributable to the method of water treatment.

In fact, the reduction of water-borne typhoid and other intestinal disorders has been striking not only in Washington but also in all cities where modern water treatment is practiced. Other cities faced opposition from unorganized groups who confused alum used in baking powder (then being crusaded against) with alum used as a water-treatment chemical, but no documentation of opposing opinions equals that derived from the Senate hearings in the Washington case.

Chlorination Proved Beneficial

After chlorination was first practiced in 1908 at the Chicago Stock Yards Plant and at the Boonton Reservoir of Jersey City, N.J., sanitary engineers and public health officials in the United States became greatly interested in the process as a means of reducing the bacterial content of public water supplies. Fortunately the installation of chlorination equipment proceeded without much fanfare. The decision to chlorinate was often made by management, without public discussion, as a step in water supply improvement. The annual death rate from typhoid and other water-borne diseases was still high in most cities, but it soon became evident that chlorination was producing highly beneficial results.

The most conspicuous opposition to chlorination developed in Massachusetts when one of the members of the State Department of Health firmly opposed chlorination of any impounded public supply under his jurisdiction. His theory was that the sources had not been polluted and that chlorination was not needed.

It should be remembered, however, that before the work of E. B. Phelps, Mr. Ellms, S. J. Hauser, Mr. Wolman, Linn Enslow, A. M. ASCE, and others, chlorination proceeded on a rule-of-thumb basis depending on results of bacteriological examination of the water before and after treatment. The delays resulting from this method were often responsible for chlorinous tastes in the treated water and in turn for sporadic public complaint.

Of all the opposition to chlorination, the most serious in its possibilities was a communication addressed to the city officials of an Illinois city about 1910. The State Water Survey had recommended that the public supply be chlorinated and a member of the city council had written to Harvey W. Wiley asking his opinion of chlorination. As Food Chemist of the U.S. Department of Agriculture during the "dawn" of food sanitation, Dr. Wiley had an international standing as an opponent of food adulteration. He had vigorously combated the use of such things as benzoate of soda in catchup and formaldehyde in milk, and had built up a great following. When the request for comment concerning chlorination came to him, he did not take the time to examine the problem in detail, but replied that "chlorine is an adulterant chemical that should no more be used in water than formaldehyde in milk." Fortunately, the letter received little publicity. Dr. Wiley forgot about chlorination.

Liquid chlorine, instead of chlorinated lime, began to be used in the disinfection of water about 1912. Messrs. Ellms and Hauser in Cincinnati and Wolman and Enslow in Maryland developed methods for the prompt evaluation of the adequacy of treatment with chlorine. Men in service in World War I came home with a firm belief in the protective value of chlorination. Coagulation, sedimentation, filtration, and disinfection had become the fabric of water purification.

In the last one hundred years the number of urban water supplies in the United States has increased from 68 to more than 15,500. During the century, the water-served population has grown from less than a million to almost a hundred million. More striking than this simple growth, however, is the improved sanitary quality of public supplies. In 1900, large cities lost an average of more than 50 persons per 100,000 each year by death from typhoid fever alone. About that time, Mr. Hazen pointed out that improved water quality had already demonstrated that, for every death from typhoid fever prevented by improved water quality, at least two additional deaths from other related causes were prevented.

Water treatment as now practiced, with effective coagulation, sedimentation, filtration, and disinfection, reached a reasonably efficient state by 1920. (This statement should not be taken as disregarding the great improvements that took place during the ensuing 30 years.) Today less than 1 typhoid death occurs per 100,000 population. Therefore, let us assume that for the 30-year period, 50 typhoid deaths and 100 related deaths per 100,000 population have been prevented by water-quality control. During this period the average water-served population has averaged about 75,000,000 persons. Thus, the "life-saving" credit for improved water supply during the 30-year period ($750 \times 150 \times 30$) amounts to 112,500 persons per year, or a total of 3,375,000.

Fluoridation of water is now considered by all as a new and novel element in water-quality control. In 1945, communal fluoridation of public water supply was initiated at Grand Rapids, Mich., Newburgh, N.Y., Evanston, Ill., and Brantford, Ont., Canada; and by December, 1951, more than 200 cities had adopted the process.

Fluoridation, it should be understood, is not a protective treatment such as coagulation, filtration, or disinfection nor is it a medication. It is an adjustment of the chemical make-up of the water intended to maintain sound teeth and thus indirectly improve the general health. Growing children are thus provided with a dietary component known to exist in proper amount in many natural waters where dental caries is infrequent. Its introduction in any community water supply depends on support and advocacy by the dental and medical profession. The water works industry cooperates in, but does not promote fluoridation. However, the practice is coming to be recognized as an important element in the service of public water supply.

(This article is based on the paper presented by Mr. Jordan in the symposium on Outstanding Achievements in Sanitary Engineering a a joint session of the Sanitary Engineering Division and the Engineering Section of the American Public Health Association, presided over by Rolf Eliassen and Ralph E. Fuhrman, members of the Division's Executive Committee, and Dwight F. Metzler, A.M. ASCE, at the Centennial Convention in Chicago.)

ROY J. MORTON, M. ASCE

Leader, Radioactive Waste Disposal Research and Development Section, Health Physics Division, Oak Ridge National Laboratory, Oak Ridge, Tenn.

Radioactive contamination, continuing problem in water supply engineering

Recent developments in the field of nuclear energy have created potential health hazards whose evaluation and control are sanitary engineering problems. Among these problems is the possibility that, in the future, water supplies in this country may contain greater amounts of radioactive materials than in the past. Whether the increase in radioactive water contamination will be generally appreciable or will cause significant hazards in a particular locality cannot be predicted.

Many publications and discussions have pointed out that the public health problems due to radioactivity are new, complex, and technically different from other problems of environmental sanitation. However, the sanitary engineer who may be faced with these problems must not be overawed by their novelty and difficulty or diverted by the idea that he must become a nuclear physicist before he can attack them. In principle, the sanitary engineering problems of nuclear energy operations are similar to other problems of sanitary control.

The maximum permissible concentration (MPC) values for drinking water, as now being established, are those values that will not permit an accumulation of radioactive materials in any organ of the body such as would result in an exposure greater than the maximum permissible exposure. The Subcommittee on Internal Dose of the National Committee on Radiation Protection has developed and recommended MPC values for many individual radioisotopes and for unknown mixtures of radioactive materials. The recommended values for unidentified radioactive contaminants in air and water for long-term continuous use are given in Table I. The MPC values recommended for concentrations of selected radioisotopes that are of particular interest in this discussion are given in Table II. The present suggested emergency limits for radioactive water contamination following an atomic explosion are given in Table III.

The sources of radioactive materials that, potentially, might affect water supplies may be grouped in four general classes: nuclear reactors and associated operations; use of radioisotopes in research laboratories, hospitals, and industries; use of atomic weapons or radioactive isotopes in warfare; and naturally occurring radioactive materials.

Use of radioisotopes in laboratories, hospitals, and industries is increasing continually although it still involves relatively small quantities of radioactive materials. Nearly all the radioisotopes for such uses are distributed and controlled by the U. S. Atomic Energy Commission. In a recent review of the radioisotope program of the Commission, F. W. Kittrell indicated that, from the beginning of this program in August 1946 through December 1951, a total of 2,771 curies had been distributed. This distribution has included more than 19,000 shipments to over 600 institutions located in 46 states in the United States. The review gives several examples of the methods of calculating the dilutions that would be required for known quantities of various radioisotopes in order to reduce the concentrations to the permissible values for drinking water.[3]

Preventive and Control Measures

Assuming that a broad program for the systematic control of potential radioactive contamination of water supplies may become necessary, the preventive and control measures may be classified generally in the same way as measures for the control of bacteria or of other chemical contaminants. These measures include:

1. Further definition and establishment of values for the maximum permissible concentrations of radioisotopes in drinking water and interpretation of these values in terms of water works practice covering the expected range of operating conditions.

2. Basic research and practical developmental studies concerning radioactive waste processing methods that will aid in the prevention of discharges of contaminants to water supply sources, the numerous factors that influence the dispersion, behavior, and reduction of radioactive contaminants in natural waters, and methods for the removal of contaminants from water supply systems, particularly by conventional and modified water treatment procedures.

3. Basic and practical instrument development studies and the design and appraisal of instruments to enable the detection and measurement of radioactivity at the levels, and under the conditions, that are of practical significance, such as the measurement of natural background concentrations and low levels of radioactive contaminants in water for long-term use, and the higher levels of emergency contamination that may result from accidents or from the use of atomic weapons.

4. Educational opportunities and the dissemination of information for the sanitary engineers and water works officials who are responsible for drinking-water quality.

In the movement of radioactive water contaminants from their sources to a water supply system, there are three general stages, in any or all of which major reductions in the level of radioactivity may be effected.

These stages are: (1) the release or escape from the source of radioisotopes into a body of surface or underground water; (2) the travel of the water to the water supply intake; and (3) the passage of the water through the water plant and into the distribution system. As regards (1), the Oak Ridge National Laboratory has developed a monitoring installation

for sampling and measuring radioactivity in its waste water (Fig. 1).

The various methods of reduction include: (1) the processing of radioactive wastes, with separation and retention of potentially dangerous water contaminants; (2) removal of the radioisotopes from the water by natural agencies or processes before it reaches the water works intake; (3) removal of the radioactive materials by water treatment; and (4) reduction of the level of contamination by radioactive decay.

There are numerous physical, chemical, and biological factors which influence the dispersal and the behavior of radioactive elements in surface and underground watercourses, and more or less reduction in the radioactive constituents prior to the use of the water may be expected as a result of these factors. Although no general quantitative conclusions can be stated, studies have indicated that the concentration of most of the radioisotopes will be markedly reduced and that some radioactive elements will be removed almost completely under natural conditions if the time of water travel is considerable.

The removal of radioisotopes by a treatment process will depend on the characteristics of the particular radioelements and upon the various conditions of treatment. The probable effectiveness of water treatment in the removal of radioisotopes can be ascertained only from specific data obtained by careful experimentation and by experience. An adequate range of data is essential in order to represent the prevailing conditions of the raw water, of the radioactive contaminants involved, and of the treatment facilities and operation.

There has developed, unfortunately, a rather widespread impression that conventional water treatment will provide sufficient removal of any and all kinds of radioisotopes and that the passage of water through a treatment plant affords protection without measurements and regardless of the initial contamination. This is not the case. Some radioisotopes are readily and fairly completely removed by conventional coagulation and filtration, but others may be removed very slightly or not at all by such procedures. The detailed data now available from water treatment studies indicate that the removals to be expected from coagulation, sedimentation, and filtration may be summarized as follows:

1. A maximum reduction of 90 to 98 percent might be accomplished for readily removed elements such as yttrium, zirconium, niobium, phosphorus, the rare earths, and probably such other materials as would precipitate if present in macroscopic amounts under the conditions of flocculation.

2. Less than 10 percent removal would be expected under normal conditions for materials that are d fficult to remove by flocculation. Examples of such elements are iodine, ruthenium, and cesium.

3. In the conventional treatment of water contaminated with mixed fission products, such as those that might result from an atomic explosion, 60 to 80 percent removal might be expected in normally operated plants employing alum or iron coagulation, and between 90 and 99 percent removal might be obtained in softening plants or under conditions where high pH values prevail.

It should be emphasized that the efficiencies of removal outlined above may or may not be adequate to provide a safe water in a particular situation. This will depend on the concentration of radioactive materials in the raw water and the MPC values for the radioisotopes remaining in the water after treatment.

Measuring Radioactivity in Water

All studies and control procedures relative to radioactive materials depend on the ability to measure the levels of the radioactivity that is present. For many purposes it is necessary to separate, identify, and measure the amounts of the individual radioisotopes by radiochemical techniques which often involve difficult and laborious procedures. A very large number of radiation detection instruments and radio-assay techniques have been developed and used in the field of atomic energy. Of these, many are useful in the study of water contamination problems, and a few can be adapted for the needs of routine water works control.

The concensus of the American Water Works Association's Task Group on "Instrumentation and Methods for Testing Radioactive Contamination in Water," regarding the useful application and range of detection sensitivity for the several instruments, may be summarized as follows: (1) portable Geiger-Müller beta-gamma survey meter—for rapid field surveys during civilian defense emergencies requiring detection in 150 milliliters (ml) of water of radioactive contamination ranging from 10^{-3} to 1 microcurie per ml; (2) electroscopes (such as the Landsverk analysis unit) for water works laboratory tests during a civilian defense emergency requiring a range of sensitivity (without evaporation of the sample) of 10^{-4} to 1 microcurie per ml; (3) continuous indicating and recording monitor—for continuous monitoring of a water supply for relatively high levels of contamination due to atomic bombing, radiological warfare, sabotage, or accidental spill of atomic wastes requiring a sensitivity of 10^{-4} to 10^{-1} microcuries per ml; and (4) proportional counters (or other types of counting assemblies) for precise measurements from extremely low levels to very high levels of radioactivity requiring sensitivities from approximately 10^{-8} to 1 microcurie per ml or higher.

A number of instruments applicable to water monitoring problems or field surveys for the detection of low levels of radioactivity have been developed in the Health Physics Division of the Oak Ridge National Laboratory. Those listed below are

FIG. 1. Concrete weir box and associated equipment is typical installation for measurement of flow and continuous proportional sampling of waste water before release. At Oak Ridge National Laboratory, entire waste stream, exclusive of sanitary sewage, is measured and sampled at this point. Installation includes standard 90-deg V-notch weir (lower center), corrugated metal floatwell and water-level recorder according to USGS standard specifications (upper left), Trebler proportional sampler with timer for control (revolving scoop shown in right center with timer above), discharge pipe from sampler to stainless steel sample container (lower right, outside weir box), and space at upstream end of weir box for installation of monitoring instrument to measure and continuously record level of radioactivity in the water.

TABLE I. General Levels of Maximum Permissible Concentrations of Radioactive Contaminants in Air and Water for Continuous Exposure Beyond Area of Control[7,9]

Medium of Exposure	Maximum Permissible Concentrations* (μc/cc)† Beta or Gamma Emitter	Alpha Emitter
Air	10^{-9}	5×10^{-12}
Water	10^{-7}	10^{-7}

* To be considered as safe values until the identity of the radioisotope causing the contamination is determined, and then the recommended MPC value for that particular isotope may be used, provided such a value has been established. Safe values are those that are considered to result in damage equal to, or less than, the damage that results from ordinary and willingly accepted overindulgences, such as overeating, loss of sleep, dusty homes, improper clothing, etc. Safe values of maximum permissible concentrations of radioisotopes are considered not to produce any readily detectable biological damage.

† μc/cc = microcuries per cubic centimeter.

TABLE II. Maximum Permissible Concentrations of Certain Radioisotopes in Water for Continuous Use*

Isotope	Half Life	Body Tissue	MPC (μc/cc)†
	Alpha Emitters		
U—natural (sol)	4.5×10^{9} years	Bone	8×10^{-5}
Ra^{226}	1,620 years	Bone	4×10^{-8}
Pu^{239} (sol)	2.4×10^{4} years	Bone	1.5×10^{-6}
Po^{210} (sol)	138 days	Spleen	3×10^{-5}
	Beta and Gamma Emitters		
C^{14}	5,720 years	Fat	3×10^{-3}
H^{3}	12.5 years	Total body	0.2
Ca^{45}	152 days	Bone	5×10^{-4}
P^{32}	14.3 days	Bone	2×10^{-4}
S^{35}	87.1 days	Skin	5×10^{-3}
Na^{24}	14.9 hours	Total body	8×10^{-3}
Fe^{59}	46.3 days	Blood	1×10^{-4}
I^{131}	8 days	Thyroid	3×10^{-5}
Sr^{89}	53 days	Bone	7×10^{-5}
Sr^{90}—Y^{90}	25 years	Bone	8×10^{-7}
Co^{60}	5.2 years	Liver	2×10^{-2}
Ba^{140}—La^{140}	12.8 days	Bone	2×10^{-3}

* Values for selected radioisotopes taken from prepublication copy of report by Subcommittee on Internal Dose of National Committee on Radiation Protection.[9]

† μc/cc = microcuries per cubic centimeter.

TABLE III. Suggested Emergency Levels of Radioactivity in Drinking Water for Temporary Use Immediately Following an Atomic Explosion[10,11]

Use	Safe Concentration (μc/cc)*	Acceptable Risk (μc/cc)*
Beta-gamma activity:		
For 10-day use	3.5×10^{-3}	9×10^{-2}
For 30-day use	1.1×10^{-3}	3×10^{-2}
Alpha activity:		
For 10-day use	2×10^{-4}	5×10^{-3}
For 30-day use	6.7×10^{-5}	1.7×10^{-3}

* μc/cc = microcuries per cubic centimeter.

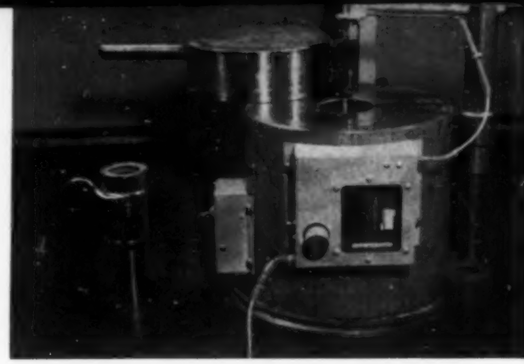


FIG. 2. Alpha-beta counter[23] can be used either for sample testing or as continuous-flow water monitor. Photo shows instrument with top raised, ready for sample handling. It can be used either with commercial GM counter or with extremely thin-walled GM counter tube of rubber hydrochloride—shown in upper center. Objects in foreground are continuous-flow water cell (left) and calibration unit solution cell (right). Scaler, timer, and tank containing gas

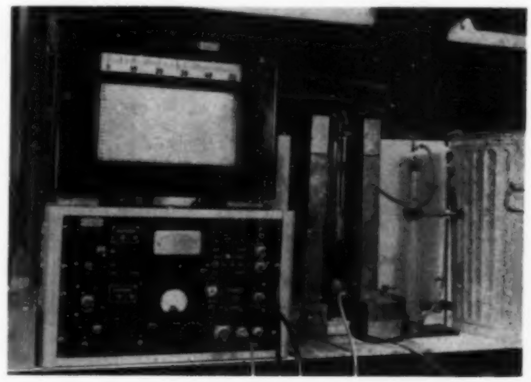


FIG. 3. Column-type, low-level water monitor[24] includes, from left to right, counting-rate meter with Brown recorder, counter column in lead brick shield (front removed), glass bead column air trap, and feed tank (metal can). Feed pump is back of column. Column, of lucite, contains high-capacity ion-exchange resin in contact with GM counter tube. Water passes downward through column and radioactive substances are removed from water by resin adjacent to counter. With proper calibration, low levels of radioactivity in water can be determined with high sensitivity.

now in experimental or regular use and reports concerning them are available or in prospect as indicated:

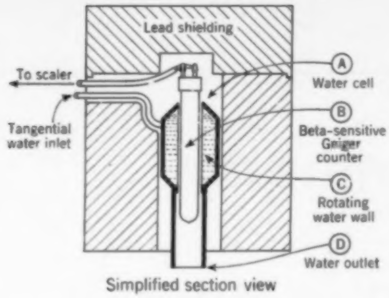
1. A continuous-flow water monitoring cell, and an associated rotating calibration unit (Fig. 2) for measuring alpha activity of about 10^{-5} microcuries per cc and beta-gamma activity at about 10^{-6} microcuries per cc, has been developed and reported by W. M. Hurst.[23]

2. A column-type unit (Fig. 3) containing ion exchange resins in contact with a Geiger-Müller tube detector has been developed and reported by Emmons and Lauderdale.[24] This instrument, which is in regular use for the counting of radioactivity in low-level samples of natural waters, is capable of measuring levels of radioactivity below 10^{-8} microcuries per cc.

3. A scanning instrument for measuring beta and gamma activity (Fig. 4) in stream water or in bottom sediments, contains 12 thin-wall Geiger-Müller counter tubes in a waterproof housing and may be used in waters and for measuring radioactivity in sediments under water to depths of 90 ft. This instrument, which has been used extensively in bottom-sediment surveys, was developed by J. M. Garner.

4. A probing detector with an associated cable-reel device, and mounted on a trailer, has been developed for routine use in the logging of radioactivity in drilled wells up to 250 ft in depth. This instrument, which is in regular use for the radiologging of test wells in the Oak Ridge National Laboratory area, was also developed by J. M. Garner.

During the past several years there has been an understandable tendency to think of potential radiation hazards, including radioactive contamination of water, primarily as an aspect of atomic warfare. However, the peacetime problems of atomic energy development should be given the greatest study for the



for counter are not shown. Simplified section view shows arrangement for monitoring of continuous flow. Vertical water wall is maintained by centrifugal force from rotation of flowing water in water cell (or, for samples, by rotating solution cell by motor drive at 1,800 rpm). This unique feature increases sensitivity of detection and avoids build-up of contamination on tube, as there is no contact with water being tested.

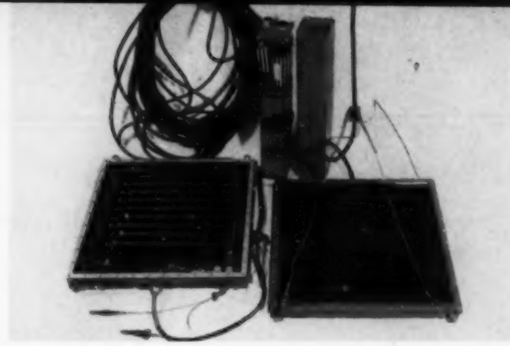


FIG. 4. Scanning instrument for detection of beta and gamma radiations in water and in bottom sediments, as shown in two models, is in process of trial and calibration for surveys of surface waters, particularly lakes and reservoirs. Gamma detector at left has cover removed to show arrangement of twelve thin-walled GM counter tubes.

following reasons. First, the nature and extent of the future problems of atomic energy are unpredictable and time will be required to cope with them. Second, the ability to act quickly and effectively in an emergency depends on the techniques and skills that have been developed from routine practice.

For example, the ability to avert a typhoid epidemic or to handle a water works safely when subjected to a flood is not acquired mainly by specific preparation for such an emergency. Similarly, the basis of ability to cope with radioactive contamination is experience in the routine detection, prevention, and elimination of the less dangerous or less extreme degrees of contamination. The sound basis for civil defense emergency plans is an established long-range program of water quality control.

The author is grateful to his associates in the Radioactive Waste Disposal Research and Development Section and to others in the Health Physics Division for information and other assistance in the preparation of this paper. The water treatment studies mentioned are part of a joint cooperative program of research by the U. S. Public Health Service and the Oak Ridge National Laboratory, under the auspices of the U. S. Atomic Energy Commission.

(The extensive report, of which this article is a brief abstract, was presented by the author before a joint session of the ASCE Sanitary Engineering Division and the Engineering Section of the American Public Health Association, presided over by B. A. Poole and John C. Bumstead, members of the Division's Executive Committee, and Earnest Boyce, chairman of the Division's Committee on Advancement of Sanitary Engineering, at the Centennial Convention in Chicago, Ill.)

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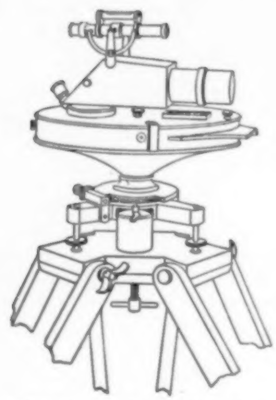


FIG. 1. Photographic plane table designed in 1858

Photogrammetry comes into its own

GEORGE D. WHITMORE, M. ASCE, Chief of Technical Staff, Topographic Division

U. S. Geological Survey, Washington, D.C., and President, American Society of Photogrammetry

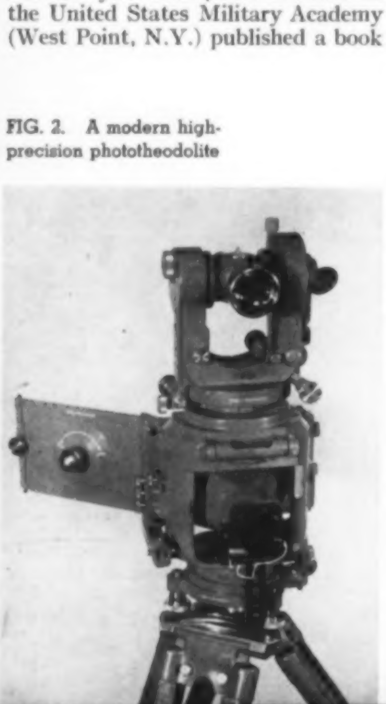
MORRIS M. THOMPSON

Staff Engineer, Photogrammetry, Topographic Division, U.S. Geological Survey, Washington, D.C.

There seems to be a rather widespread notion, even among some surveyors and mappers, that photogrammetry is newfangled, an infant prodigy that has yet to establish itself as a full-fledged science. It may therefore be a surprise in some quarters that this article can discuss one hundred years of photogrammetry. Yet it was in 1852, the year of the founding of the American Society of Civil Engineers, that a French army officer, Aimé Laussedat, produced the first maps ever made from photographs. As far back as 1888, Lt. Henry A. Reed, an instructor at the United States Military Academy (West Point, N.Y.) published a book entitled *Photography Applied to Surveying*, in which the first chapter was devoted to a history of photogrammetry. Since the time of Laussedat, the science of photogrammetry has developed continuously until it has now reached the status of a major engineering technique.

In looking back over a century of photogrammetry, our purpose is not so much to delve into the historical details of bygone phases of photogrammetry (in itself an interesting subject), as to gain a new perspective. Although photogrammetry is used for many purposes, this article will be confined to photogrammetry as applied to surveying and mapping.

FIG. 2. A modern high-precision phototheodolite



What Is Photogrammetry?

As defined by the American Society of Photogrammetry, photogrammetry is the science or art of obtaining reliable measurements by photography. Terrestrial photogrammetry is photogrammetry using ground photographs, aerial photogrammetry is photogrammetry using aerial photographs, and stereophotogrammetry is photogrammetry using stereoscopic equipment and methods.

On reviewing a century of experience, we will find that each of these three kinds of photogrammetry has a specific set of objectives and that each is also subject to a specific set of problems or limitations. The objectives and limitations are the constant factors from which we can orient and evaluate specific developments of the past.

Terrestrial Photogrammetry

In the first attempts at photographic surveying the plane table was replaced by a measuring camera (Fig. 1). The camera was equipped with a leveling device for maintaining the photographic plate in a vertical plane and a compass for reading the bearing of the optical axis of each exposure. Its purpose was identical with that of plane-table surveying—to locate objects on a map by the intersection of conjugate lines of sight from the ends of a known base. The camera procedure had an advantage over plane-table methods in that the field work could be done quickly and that any desired point in the field of view could later be located on the map in the office, at the map maker's convenience. Laussedat, who pioneered the method in the 1850's, developed a mathematical analysis for converting overlapping perspective views into orthographic projections on any plane. This procedure permitted the determination of the elevation as well as the position of any point visible in two overlapping photographs.

There is nothing fundamentally wrong with the measuring camera procedure. Laussedat and others used it to produce useful maps a century ago, and it is still the basis of modern terrestrial photogrammetry. Today, however, the crude apparatus of the early days has given way to phototheodolites (Fig. 2) of the utmost precision. In one current application

FIG. 3. Camera attached to basket of captive balloon, 1884

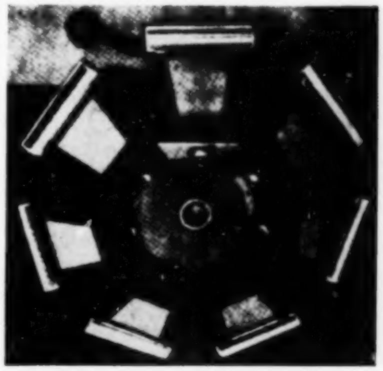


FIG. 4. Scheimpflug's eight-lens camera, bottom view, 1904

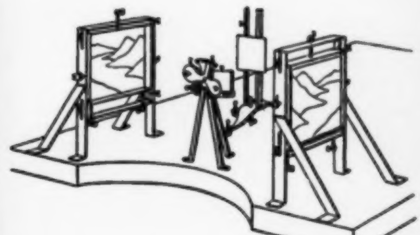


FIG. 5. Deville plotter, 1890

of terrestrial photogrammetry, the U. S. Geological Survey uses the phototheodolite in certain types of mountainous terrain to obtain fourth-order elevations for aerial photogrammetry.

Early plane-table photogrammetry and terrestrial photogrammetry in general also had limitations. Since the first lenses had a narrow field of view, a very large number of photographs was required, an item of great expense in those days and always a matter of inconvenience. In addition, photographic quality was poor. Pioneer efforts to solve the narrow field problem were centered chiefly on panoramic cameras, the first of which appeared as early as 1858. Their purpose was to give a continuous view by successive exposures on a strip of film. Some of these cameras were arranged to photograph only a part of the horizon, whereas others covered the entire 360 deg. The panoramic camera is still being used, notably by the U. S. Forest Service to photograph full horizons from lookout towers, in order to detect and locate forest fires.

With modern wide-angle lenses, narrowness of field is no longer a serious problem. However, terrestrial photogrammetry still has certain inherent deficiencies of major importance. For mapping purposes, the field of view commanded by a ground station is much inferior to that commanded by an air station. The conversion from a terrestrial perspective to the map plane is, at best, a cumbersome process. Every ground station must be occupied by field surveying parties, just as when plane-table methods are used, and hence the saving in cost or time is not pronounced.

Superiority of Air Stations

The superiority of the aerial camera station over the ground camera station was recognized from the very beginning of photogrammetry. In 1858, Laussedat experimented with an aerial plate camera, first supporting it from a string of kites and later attaching it to a captive balloon. The results of these experiments were not satisfactory since it was difficult to take a sufficient number of photographs from one station to cover all the area visible from that position. In addition, the slow shutters of that day made it extremely difficult to obtain sharp photographs because of the oscillation of the balloon. Laussedat eventually abandoned the aerial method and returned to terrestrial photogrammetry.

Others experimented with aerial photography, using balloons (Fig. 3), kites, and even carrier pigeons, but it was not until the close of the century that Theodor Scheimpflug, a captain in the Austrian army, provided a feasible solution for the problem that had baffled Laussedat. To obtain complete coverage of the visible area from a camera station, Scheimpflug used an eight-lens camera attached to the basket of a captive balloon. This camera (Fig. 4) consisted of seven lenses taking oblique photographs grouped around a central lens taking a vertical photograph. The eight exposures were transformed into an extremely wide-angle, single, composite photograph, by a universal transforming printer. Following Scheimpflug's work, there was a period of development of multiple-lens cameras, ranging from three to nine lenses, all with the single objective of obtaining wide photographic coverage from a given air station. The wide coverage of multiple-lens cameras is still considered very advantageous in some types of mapping. A nine-lens camera is used by the U. S. Coast and Geodetic Survey in this country and by at least one commercial organization in Europe.

Even with captive balloons, ground crews were still necessary to move the cumbersome apparatus across the countryside, a slow and costly operation. Free balloons, propelled by electric motors, were in use as early as 1884, but they were not used extensively for photography. Possibly the oscillations were so great that their use was impracticable.

Aeronautical developments changed the situation completely in the early part of the twentieth century. A German zeppelin captured in France in August 1914 was found to be equipped with an aerial camera, as was an airplane shot down later in that year. This was a development of the utmost significance. The camera could now be carried to the

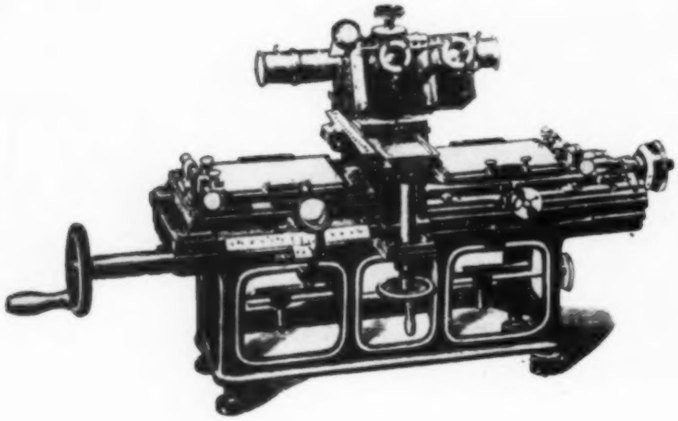


FIG. 6. Stereocomparator, 1901

desired aerial exposure station easily and rapidly without the necessity of placing a crew in the area to be photographed.

Conceding that there are a number of ways of utilizing aerial photography, the writers will confine themselves to problems connected with map making from single-lens vertical photographs using a plotting instrument. A vertical photograph is one taken with the optical axis of the camera nearly vertical or, in other words, with the plane of the photograph nearly parallel to the earth's surface. If the plane of the photograph were exactly parallel to the earth's surface at the time of exposure and if the surface of the earth were perfectly flat, the photograph would represent a true map. However, the airplane noses and rolls as it flies its course, so that the photograph is invariably tilted to some degree. As a result, the image of the earth's surface on the negative does not have a uniform scale. Furthermore, the relief of the terrain causes local displacements of the image. These are fundamental geometrical properties of the photograph arising from the orientation of the camera and the nature of the terrain. In addition, the image is distorted by the physical imperfections of the photography, such as lens aberrations, camera movement during exposure, film curvature, and film shrinkage. Because of these three factors—tilt, relief, and photographic imperfections—the task of converting aerial photographs into accurate topographic maps presents a formidable, but by no means insurmountable, problem. Some methods of solving this problem will now be examined.

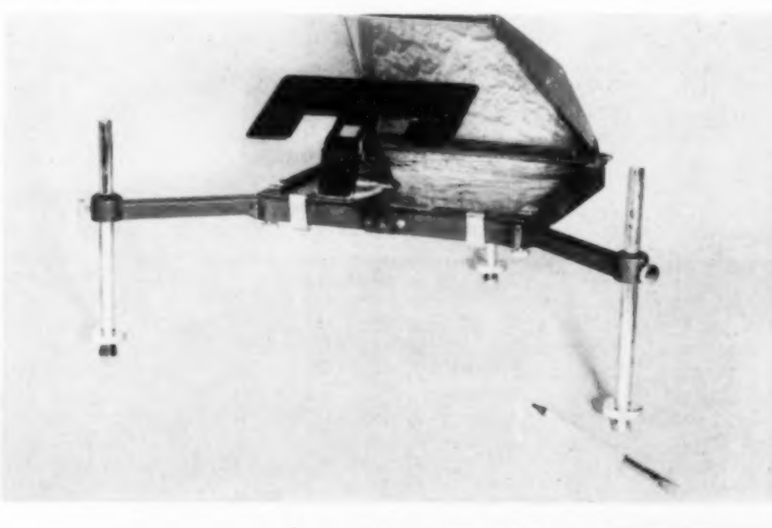
Application of Stereoscopy

When the problems of aerial photogrammetry or terrestrial photogrammetry are solved by the use of stereoscopic instruments, the procedure is referred to as stereophotogrammetry. It should be understood that stereoscopic plotting instruments do not offer the only solution to these problems. For example, the radial-line method of plotting, known as early as 1893, with its corollary, the slotted templet method, has a wide and useful application in photogrammetry. The positions of points in the radial-line method are plotted in their correct relative position to one another by a system of intersection and resection, using the radial center of each photograph as the origin of radials through the images of the points. There are also strong, although somewhat tedious, analytical methods of solution based on parallax measurements.

By far the greater part of photogrammetric mapping, however, is done with stereoscopic plotting instruments. The parlor stereoscope was a familiar instrument of the late nineteenth century, and photogrammetrists were quick to recognize the possibilities of three-dimensional viewing of photographs for surveying purposes. A stereoscopic plotting instrument (Fig. 5) for use with terrestrial photographs was devised about 1890 by E. Deville, Surveyor-General of Canada. This was probably the first such instrument to prove of practical value. At about the same time, the Italian Professor Porro and the German Professor Koppe developed the important Porro-Koppe principle of overcoming the effect of camera lens distortion by observing the photograph through a lens identical to the camera lens.

A fundamental problem in the utilization of stereoscopic principles was the necessity of devising a method of horizontal and vertical measurement in the stereoscopic model. In

FIG. 7. Sketchmaster



1892, Stolze, of Germany, discovered the principle of the floating mark, and soon therafter his compatriot Pulfrich developed a practicable method of measuring with floating marks. These advances opened the way for the development of modern stereoscopic plotting instruments.

The catalog of stereoplotting instruments is long and varied. They range from simple and inexpensive instruments of low accuracy to intricate and costly machines of the highest precision. Most of these instruments have a useful function for some specific purpose. If only form lines are required, there is no need to have a precision instrument. If high precision is required, it cannot be obtained with a low-cost instrument.

The problem of tilt and relief displacements is solved in the same general manner in most stereoplotting instruments, although there are wide differences in the mechanical details and in the degree of accuracy attained. A pair of overlapping photographs is oriented in the instrument to recover the relative orientation of the negatives at the instant of exposure. A stereoscopic viewing system is provided so that a miniature model of the terrain appears to be created. The model can be brought to the desired scale and oriented with respect to a datum, as represented by ground-survey control points. Measurements are made, and map detail is transferred to the manuscript sheet, by a floating mark. Since the space model is similar in every respect to the terrain in nature, the tilt and relief displacements are automatically solved. As the clarity and geometrical accuracy of the model and the precision of transferring detail to the map increase, the accuracy of the map produced increases and so, very likely, does the cost of the instrument.

The mechanical and optical problems involved in the design of stereoplotting instruments are multitudinous, and often very complex. Beginning with the development of the Stereocomparator (Fig. 6) by Pulfrich in 1901, there has been a steady stream of plotting devices with many variations in mechanical and optical details. But practically all have the fundamental objective of recovering the original relative orientation of the photographs as a step toward creating a space model. These devices may be roughly classified as follows, in ascending order of accuracy and cost:

1. Simple non-stereoscopic instruments for limited purposes, such as the Sketchmaster (Fig. 7), which do not provide a three-dimensional model.
2. Topographic mapping instruments utilizing paper contact prints, such as the KEK plotter (Fig. 8).
3. Topographic mapping instruments utilizing anaglyphic projection, such as the Multiplex (Fig. 9).
4. Topographic mapping instruments utilizing optical or mechanical-optical trains, such as the Autograph A-5 (Fig. 10).

The problem of imperfections in the original photography, common to all plotting methods, has never been wholly solved. There are various methods for compensating the effects of camera lens distortion and film shrinkage, but the real solution is the elimination of these effects at the source. There has been some progress in this direction recently. New photogrammetric lenses, virtually distortion free, have become available and plans have been made for the installation of some of these in aerial cameras. One solution of the film shrinkage problem is the use of glass plate negatives, but this is expensive and inconvenient. A new plastic-base film of very high dimensional stability has been announced, and may aid in eliminating the shrinkage problem.

Only in the last decade or so has photogrammetry had a really profound influence on the economics of surveying and mapping. Until about 1935, photogrammetry had operated, relatively speaking, solely on the fringes of the broad field. However, when the full impact of a century of development was brought suddenly to bear, under the urgent necessities of World War II, the effect was revolutionary and permanent. Within the last ten years photogrammetry instead of field work with the plane table has become the basic procedure for the making of topographic maps and for many other activities in the surveying field. This does not mean that field work is a thing of the past. Field engineers

FIG. 8. KEK plotter

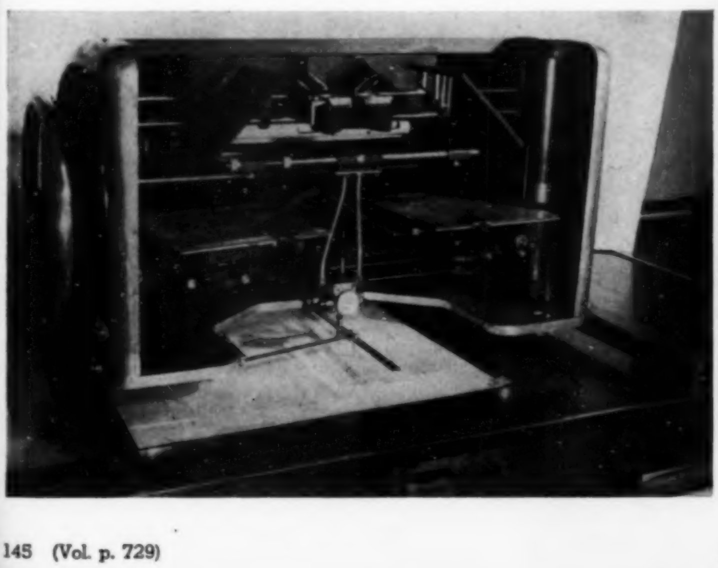
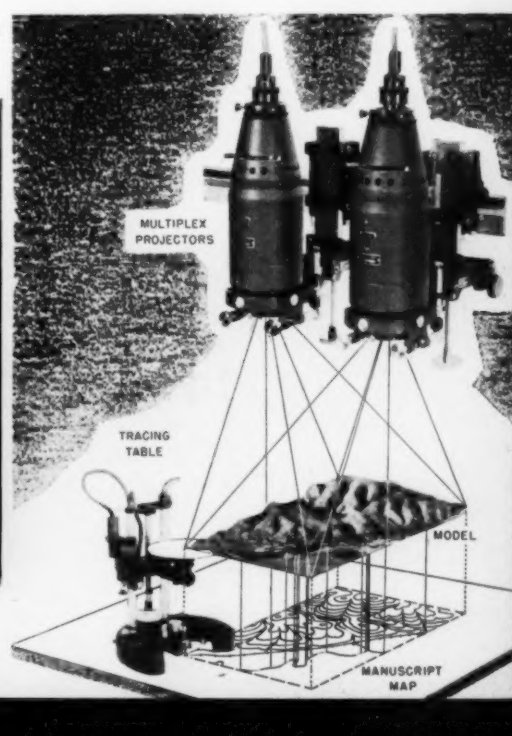


FIG. 9. Principle of the Multiplex



are still needed in considerable numbers for control surveys, for completion surveys, and for contouring flat terrain. But the undeniable fact is that, in major mapping enterprises, field operations are now supplementary to photogrammetric operations and must be tailored to fit the photogrammetric program.

Such a revolution, which has affected governmental and commercial mapping organizations alike all over the world, would not have come about unless it paid in dollars and cents. Relative costs of field mapping versus photogrammetric mapping are not easy to evaluate for there is always the debatable question of how to amortize expensive plotting equipment and the additional service operations that are an inescapable part of photogrammetric precedures. However, photogrammetric procedures, if not always cheaper than field procedures, at least give better maps for the same money. Over and above the measurable cost per square mile of mapping, photogrammetry permits the completion of vast mapping projects within a time interval beyond the range of practicability for field methods. Considering that in many instances time is money, the economics of the situation consistently dictates the use of photogrammetric methods for extensive mapping projects.

The economics of photogrammetry has also brought a perennial mapping problem—the cost of ground-survey control—into sharper focus than ever. When topography was done by plane table, field parties had to be on the ground anyway, and it seemed quite natural that they devote part of their efforts to control surveys. But now that the topography is determined from aerial photographs, the continuing need for even larger amounts of control to be done by surveying parties in the field makes everyone control-cost conscious. Indeed, the cost of control sometimes exceeds the cost of photogrammetric compilation. It is therefore only natural that intensive efforts are being made to eliminate, or at least reduce, the requirements for ground-survey control. Some progress has already been made in this direction for some classes of mapping, using air-borne radar and shoran techniques.

Mapping by photogrammetric methods has broadened the scope of skills and knowledge required. So many skills and varied scientific backgrounds are necessary that few can hope to master all of them. Thus, although the field of surveying and mapping has broadened immeasurably and has created a need for high-level scientific knowledge, paradoxically the participation of the individual in the construction of the map has narrowed. He now tends to become a specialist, participating in only one phase of the operations, whereas the old-time topographer knew the satisfaction of creating an entire map from beginning to end.

Photogrammetry Influences Society

Some might say, rather glibly, that the impact of photogrammetry on society is a rather far-fetched conception, that photogrammetrists can scarcely make their weight felt. But consider this conception further. What about the impact on society of aviation, of well-constructed highways, of the development of natural resources, of the conduct of wars? None would deny that all these have a far-reaching influence. Yet each depends on maps, maps now made largely from photographs. Take away the pilot's aeronautical chart, the detailed strip map of the turnpike planner, the conservationist, topographic or resource map, the general's military map—and society has been deprived of vital tools indeed.

Without the speed of photogrammetry, the lack of maps would constitute a bottleneck in the development of other fields whose importance is more obvious. In this way, photogrammetry constitutes a very real, if indirect, force in the pattern of our civilization.

The Crystal Ball

It is good engineering practice to predict future developments by extrapolating the trends of the past. The trend, as we have seen it in reviewing a century of experience, is toward the ever-increasing self-sufficiency of photogrammetric methods. We can look forward then to new and improved instruments and techniques, to new methods of obtaining control without recourse to ground surveys, and to an ever-increasing demand for more and better maps. At the same time, since every new development has raised its new quota of problems, we can expect that the photogrammetrist of the future, having solved the most baffling problems of today, will be vexed by questions beyond our conception.

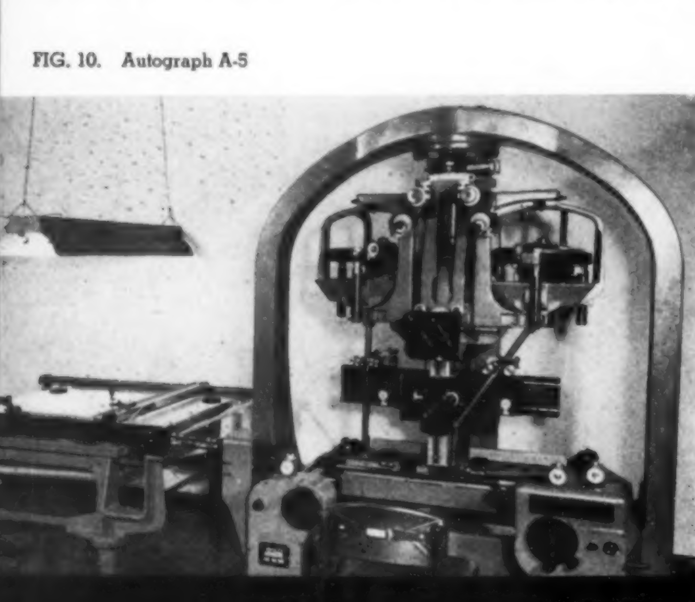
Even if distortion-free lenses, mechanically perfect cameras, absolutely stable film, faultless developing techniques, and sharp-sighted, trouble-free plotting instruments could be produced, photogrammetry would still be confronted with difficult and interesting problems. In areas of heavy timber cover, the ground would still be invisible to the camera. Adequate ground control would still be difficult to obtain in remote or inaccessible areas. Personnel sufficiently skilled in both the science of photogrammetry and the art of topography to utilize the procedures to the best advantage would still be relatively rare.

Although photogrammetry has come a long way technically since 1852, it has still a long way to go.

(*Figures 1 and 3 are from* Photography Applied to Surveying, *by Lt. Henry A. Reed, John Wiley & Sons, New York, copyright 1888, reproduced by permission. Figures 4, 5, and 6 are from* Photogrammetry *by O. von Gruber, American Photographic Publishing Co., New York, 1942, also reproduced by permission. All other illustrations are U. S. Geological Survey Photographs.*)

(*This article is based on the paper presented by the authors at the Surveying and Mapping Division session presided over by W. H. Rayner, chairman of the Division's Executive Committee, at the Centennial Convention in Chicago.*)

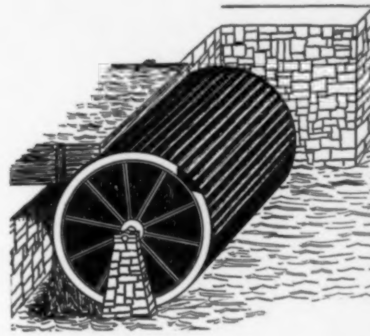
FIG. 10. Autograph A-5



One hundred years of water power

W. F. UHL, M. ASCE

Consulting Engineer and President, Chas. T. Main, Inc., Boston, Mass.



This breast wheel is one of several 16-ft-dia cast-iron wheels installed in Prescott Mills, Lowell, Mass., 1844. From ASCE *Transactions*, 1922, Paper No. 1503, by A. T. Safford, M. ASCE, and E. P. Hamilton.

Development of water power during the last 100 years covers approximately the second and third phases of such development. There was a fairly distinct break in the art of water power development and the use of water power about 100 years ago and again about 50 years ago, representing these two phases and covering the period in which we are more particularly interested at this time. However, for the sake of continuity it may be of interest to review briefly the first phase of water power development.

This first or earlier phase goes back to ancient times and in this country covers a period of over 200 years (from about 1650 to 1850). It includes the early uses of water power for driving the small industries of our pioneer ancestors.

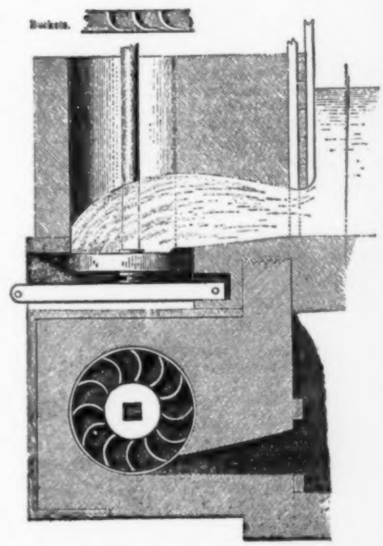
One of the earliest water power developments was constructed by Israel Stoughton in 1634 at the Lower Falls of the Neponset River between Milton and Dorchester, Mass. Here the water power was used to drive a grist mill, a saw mill, and a powder mill. In recent years a hydroelectric plant has been built at the same site. Thus, the water at this site has been in constant use for power for over 300 years. Another of the very early practical applications of water power in this country was in a tidal mill built on Mill Creek near Boston in 1631.

The grist mill was a most important community industry in the early days, and as a result many of our towns grew up around the mill dams. Since the amount of power required by saw and grist mills was small, the developments usually consisted of low dams on small streams, operating water wheels of the pitchback, overshot and undershot types, or breast wheels.

Second Phase Started About 100 Years Ago

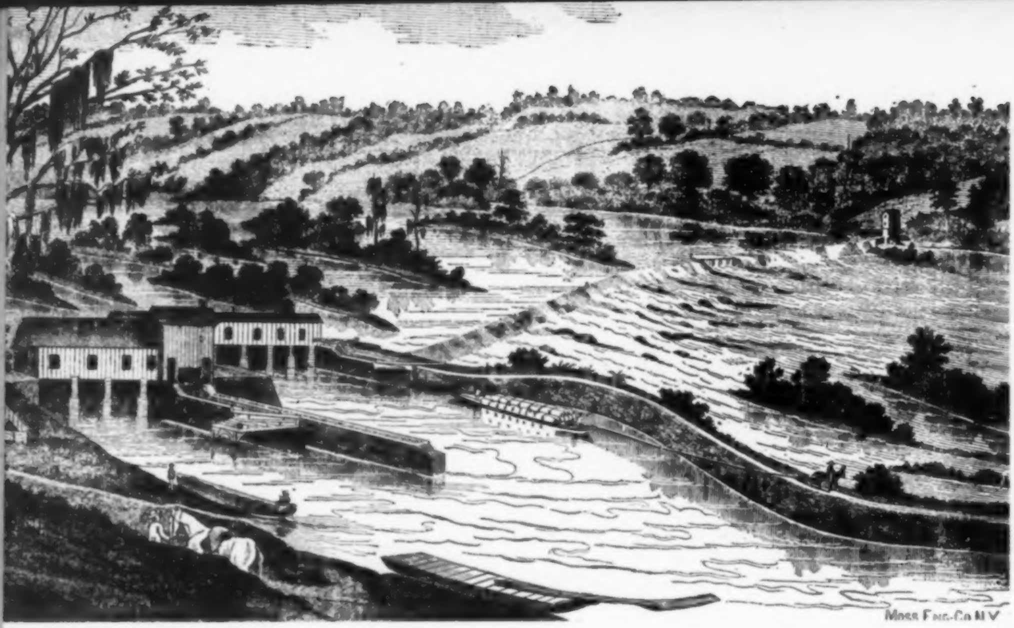
The second phase of water power development, and the era in which we are here chiefly interested, started about 100 years ago with the introduction of the then generally adopted factory system in industry. The new industries required larger amounts of power than had been previously used, and the result was larger water power developments.

About 1850 the old overshot and breast water-wheels were being largely supplanted by turbines developed by Francis and Boyden. These turbines were more readily adaptable both in physical form and in output for use with the increased require-



Tub wheel, early form of reaction turbine, is father of modern high-speed turbine. Its origin is French, as early as 1620. From ASCE *Transactions*, 1922, Paper No. 1503.

Power developed at St. Anthony Falls on Mississippi River at Minneapolis, beginning in 1848, operated flour mills and factories. These illustrations, showing the falls before and after development, are from *U.S. Census of Water Power*, Part II, 1880.



Municipally owned power development on Savannah River, built by city of Augusta, Ga., in 1847, continued in use as late as 1875. From 50-ft fall, 10,000 to 30,000 hp was available. Reproduced from *U.S. Census of Water Power*, Part I, 1880.

ments. Here again necessity was the mother of invention.

The demand of the new factory system of the times was frequently met by water power developments built on a cooperative basis on the larger rivers and led to the building of a new type of planned industrial city. The pattern of these developments was set by the practical impossibility of transmitting power, except for short distances, from the water wheel to the driven pulley by ropes, belts, gears and shafting. Therefore the energy-producing medium, water, had to be brought by a canal or system of canals to the point where the power was to be used.

In a typical development a company purchased land and water rights, and built a dam and canal system. The canals were laid out to permit the construction of industrial plants between water levels, usually with falls about 15 ft high between adjacent canals, or between the canal above and the river below. Frequently the same company laid out the entire town including streets, parks, and other facilities. The water power company sold land and water rights to power-using industries.

The first large-scale development of a city planned around water power was at Lowell, Mass. The navigation canal of the Proprietors of the Locks and Canals on the Merrimack River, founded in 1792, was utilized, together with the existing dam. The first mill on this canal, the Merrimac Co., was established in 1822.

Other similar developments on the Merrimack River were made at Manchester, N. H., and Lawrence, Mass. At Manchester the Amoskeag Manufacturing Co. in 1831 purchased land and developed water power for two small cotton mills. By 1845 the dam and most of the present canal system, and many of the mills which later formed the Amoskeag Manufacturing Co., were built. At Lawrence the development was made by the Essex Co., incorporated in 1845, and the canal system as it now exists was laid out and largely built by 1870.

Elsewhere in New England and in such other places as Cohoes, N. Y., Richmond, Va., Appleton, Wis., Augusta, Ga., and Minneapolis, Minn., similar projects were organized, which resulted in the development of many of the industrial centers of that era.

The development of water power at Holyoke, Mass., on the Connecticut River in 1848, involved the construction of a dam of unprecedented size, and the canal system comprising three levels was the largest built up to that time.

Nearly all water power development prior to 1850 was carried out east of the Mississippi River, and as late as 1880 only about 5 percent of the then 1,352,500 hp of water power development existed west of the Mississippi River.

Development of water power lagged after about 1860 for two principal reasons. One was the scarcity of suitable sites within the limitations of mechanical power transmission and the other, the then rapidly improving economy of steam power production.

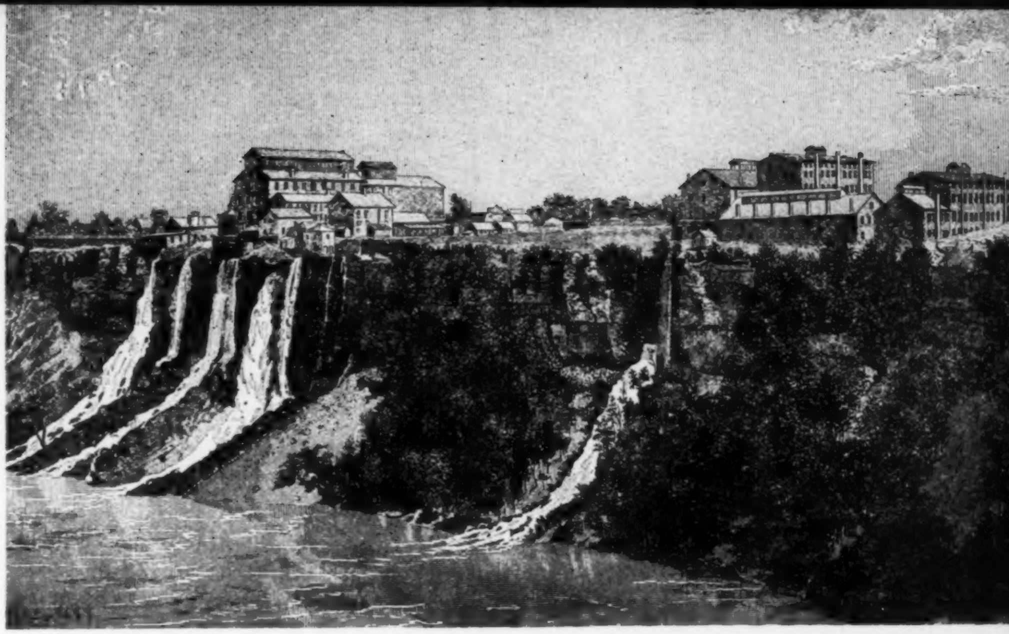
Late in the eighteenth century early forms of the steam engine were developed in Europe but their use was largely confined to pumping water. Within a period of 50 years the steam engine had been perfected to the extent that it became a dependable although expensive source of power. The development of a practical steam engine led to the establishment of industries in places where water power was not available in the quantities needed. The first of these plants were the Naumkeag Steam Cotton Mills of Salem, Mass., founded in 1845, and the Wamsutta Mills of New Bedford, Mass., built in 1846.

In 1848 the steam engine was further improved by the invention of the Corliss valve, resulting in the adoption of this type of engine in many plants either as a sole source of power or to supplement water power.

The effects of improved economy of steam power production can best be

TABLE I. Comparative Amounts of Steam and Water Power in Use, 1850–1900

Year	Horsepower of Water Power	Horsepower of Steam Power	Percentage of Total: Water	Percentage of Total: Steam
1850	662,000	488,000	57.5	42.5
1860	930,000	820,000	53.0	47.0
1870	1,205,000	1,491,000	44.5	55.5
1880	1,352,500	2,710,000	33.5	66.5
1890	1,521,500	5,904,000	20.5	79.5
1900	1,830,000	12,503,000	13.0	87.0



Hydro power development at Niagara Falls in 1882, by Niagara Falls Hydraulic Power and Manufacturing Co., was capable of supplying 4,000 hp. Wheel pits sunk 30 to 80 ft into top of cliff, with tailrace tunnels to face, utilized only part of available potential. From *U.S. Census of Water Power*, Part I, 1880.

realized from a comparison of the relative amounts of water and steam power in use during the period from 1850 to 1900. (Table I) This includes power for manufacturing, in mines and quarries, for irrigation and drainage, in electric central stations and for electric railroads.

It will be noted that the increase in use of water power from 1870 to 1880 was only about 147,000 hp, or 12 percent. In the same time the capacity of steam power plants installed for manufacturing and all other purposes for which water power was used increased about 1,219,000 hp, or 82 percent. Very little water power was used for other than manufacturing and in mines and quarries previous to 1880.

About 12,000 hp was so used in mines and quarries in 1850. By 1890 water power used for these purposes reached a maximum of 250,000 hp. By 1900 the use of water power in mines and quarries was somewhat less than 100,000 hp, having been largely displaced by steam power. By this time a substantial amount of water power was used for irrigation and drainage and for electric generation in central and railway stations.

Third Phase of Development

The beginning of the third phase of water power development in this country occurred about 50 years ago and coincides largely with the development of the art of alternating-current electric generation and long-distance transmission. In September 1882, the world's first hydroelectric station was placed in operation at Appleton, Wis. The first application of the transmission of power using step-up and step-down transformers was made at Great Barrington, Mass., on March 16, 1886.

These were small-scale experimental developments, and the first large-scale hydroelectric development did not take place until 1895, when the first important Niagara Falls plant was put into commercial operation. History records the fact that when the extensive development of water power at Niagara Falls was first seriously considered about 1890, it was thought that the best method to transmit the power to factories at relatively short distances from the Falls would be by compressed air.

The extensive development of water power which started about 1900 could not have taken place without the concurrent development of the art of transmission and distribution of electric energy, since most of our water power which was naturally adaptable for economical development was located at points somewhat remote from the market for power.

Long-distance electric transmission of energy in the United States dates from 1893, when the polyphase system was first used for carrying a current of high voltage from the plant of the San Antonio Light & Power Co., at Pomona, Calif., to San Bernardino, a distance of 19 miles. The transmission voltage was 10,000. By 1900 transmission of electric current at 40,000 volts had been accomplished. By 1909 this was successfully increased to 110,000 v and to 220,000 v by 1923.

It was the chemical and central-station industries which revived the development of water power about 1900. Between 1900 and 1910 water power development increased by over 2,000,000 hp or about 115 percent.

The development of hydroelectric power at Niagara Falls marked the beginning of the electric furnace art and the discovery and development of many materials that are now essential basic materials in American industry. Aluminum, calcium carbide, and many now common things were only laboratory curiosities prior to the development of Niagara power.

The first customer of the Niagara Falls Power Co. was the Pittsburgh Reduction Co., manufacturing aluminum. Next came the Carborundum Co., and these were shortly followed by many others making ferro-alloys, sodium, silicon, magnesium, potassium, phosphorous compounds, graphite, and the fixation of atmospheric nitrogen and many other now indispensable products. For a period of about 30 years following the Niagara development, the aluminum, pulp and paper, and some other chemical industries built their plants where large-scale low-cost water power was available within electric transmission distance.

Start of Central-Station Industry

The electric central-station industry which today produces the major portion of the power used for industrial and domestic purposes may be considered to have started with the construction of Thomas A. Edison's famous Pearl Street Station in New York City, which began operations September 4, 1882. The central-station industry expanded rapidly once the advantage of electrical generation, transmission and distribution of power was recognized.

Left: Wheeler Dam and Powerhouse was first main-river project constructed by Tennessee Valley Authority. Ultimate capacity is 260,000 kw.

Right: Bonneville Powerhouse, built on Columbia River near Portland, Oreg., by U.S. Corps of Engineers, 1933–1937, has capacity of 518,400 kw.

Although the production of steam power increased more rapidly than water power after 1860, the cost of steam power was comparatively high. As late as 1900, it required from 3 to 5 lb of coal to produce 1 hp-hr. This fact and the successful development of electric transmission of power stimulated the development of water power by this industry.

Thus the electric furnace and the art of electrical generation and transmission of power stimulated the development of water power to such an extent that it increased from 1,860,000 hp in 1900 to 14,000,000 hp in 1930. In 1900 only 13 percent of the total power capacity was water power. By 1930 water power capacity had increased to about 20 percent of the total capacity for industrial and domestic use. During the following 20 years, from 1930 to 1950, the capacity of water power plants almost doubled but increased to only about 23 percent of the total power capacity, water and thermal, by 1950.

Very little water power was developed by industry after 1930, and only about 2 million kw of such power has been developed by privately owned utilities since that date, whereas, more than 7 million kw of publicly owned water-power capacity has been developed in the same period. Water and thermal power capacity in the United States from 1900 to 1950 is listed in Table II.

It is interesting to note, as shown in Table III, that the use of electric power generated in central stations increased more rapidly after 1910 than the power generated by industries for their own use, and that the latter reached a peak about 1920.

Undeveloped Water Power

No accurate data are available regarding the amount of water power that remains undeveloped in this country. Indicative figures issued from time to time are often quite misleading. The following are terms sometimes used in estimating the amount of undeveloped water power:

1. Economically feasible
2. Technically possible
3. Engineeringly feasible
4. Within the range of possible economic feasibility

TABLE II. Water and Thermal Power Capacity, 1900 to 1950, in the United States

Year	Horsepower of Water Power	Horsepower of Thermal Power	Percentage of Total: Water	Percentage of Total: Thermal
1900	1,860,000	12,503,000	13.0	87.0
1910	4,100,000	25,860,000	13.7	86.3
1920	7,800,000	38,000,000	17.0	83.0
1930	14,000,000	55,300,000	20.2	79.8
1940	17,250,000	60,250,000	21.4	78.6
1950	26,200,000	90,500,000	22.7	77.3

TABLE III. Central-Station and Industrial-Plant Horsepower Compared, 1900–1950

Year	Total Water and Thermal Horsepower	Total Central-Station Horsepower	Total Industrial-Plant Horsepower	Total Industrial-Plant Kilowatts
1900	14,363,000	2,800,000	11,563,000	8,100,000
1910	29,960,000	8,400,000	21,560,000	15,200,000
1920	45,800,000	18,300,000	27,500,000	20,000,000
1930	69,300,000	46,500,000	22,800,000	16,200,000
1940	77,500,000	56,500,000	21,000,000	14,900,000
1950	116,800,000	97,000,000	19,800,000	14,000,000

TABLE IV. Public Water-Power Developments Under Interior Department Control, 1952

Agency	Present	Ultimate	No. of Plants
1. Operating plants, capacity in kilowatts			
Bureau of Reclamation	2,124,700	2,550,700	24
Bonneville Power Adm.	2,496,400	2,496,400	2
Southeastern Power Adm.	335,600	569,600	4
Southwestern Power Adm.	158,600	342,100	3
Bureau of Indian Affairs	10,320	10,320	2
Bureau of Mines*	22,500	22,500	1
National Park Service†	520	520	2
National Park Service	2,355	2,355	3
Total operating plants	5,150,995	5,994,495	41
2. Plants under construction			
Bureau of Reclamation	1,197,550	1,679,250	13
Bonneville Power Adm.	3,559,600	3,863,600	10
Southeastern Power Adm.	738,000	750,000	7
Southwestern Power Adm.	344,000	526,500	5
Total under construction	5,839,150	6,819,350	35
3. Authorized plants not yet under construction			
Bureau of Reclamation	1,183,900	1,499,400	28
Bonneville Power Adm.	4,074,000	4,445,000	10
Southeastern Power Adm.	1,125,210	1,543,210	20
Southwestern Power Adm.	831,100	1,163,635	19
Total authorized	7,214,210	8,651,245	77
Operating	5,150,995	5,994,495	41
Under construction	5,839,150	6,819,350	35
Grand Total of 1, 2 and 3	18,204,355	21,465,090	153

* Steam plants † Internal combustion plants

Left: Horse Mesa Dam and Powerhouse on Salt River, Arizona, were built by U.S. Bureau of Reclamation in 1927. Right: Giant among hydroelectric plants is that at Grand Coulee Dam, built by U.S. Bureau of Reclamation on Columbia River in Washington. Nine generators on each side of river will generate 3 million hp.

Estimates of water power available should state the amount available 100 percent of the time and for other percentages of time. Obviously all power available for less than 100 percent of the time is marginal power and less valuable for most industrial purposes. Such marginal power can be utilized to advantage where it can be fitted into an interconnected power system having a proportionately large amount of fuel-burning steam or other thermal power plants. Marginal power output from hydroelectric plants may well cost more than the incremental fuel costs of thermal power plants, and where this is so, the overall cost of power may well increase rather than decrease as a result of utilizing water power.

Estimates of undeveloped water power in the United States vary all the way from 50 million to 100 million hp. Fifty million hp is assumed to be available about 50 percent of the time and about 35 million hp 90 percent of the time.

Adequate field surveys of many of the streams on which undeveloped water power is assumed to exist are not available. In some cases the records of stream flow do not cover a sufficient length of time to permit reliable conclusions to be arrived at. At many sites the factors which determine the proper size of installation are unknown and can only be derived by further and more exhaustive studies.

Our records of rainfall and stream flow cover a limited period of time. However, a study of such records as we have, indicates that with time new minimum and maximum rainfall periods and consequent stream flows are experienced. Thus droughts and floods seem to become more severe. Actually, they probably are no more severe that those that occurred in past centuries. As yet our reliable records cover relatively short periods of time. Only a few rainfall records exceed 100 years and most streamflow records cover less than a 50-year period.

We now have about 26 million hp of installed water-power capacity. How much of this is dependable capacity, and for how much of the time it is dependable, is difficult to determine.

Quite accurate records of water-power capacity and output are available for public utility, municipal, and government-owned plants, covering the recent past. In 1950 the water-power capacity of these plants totaled about 17,675,000 kw (about 25 million hp), and their output amounted to about 96 billion kwhr. This was about 29 percent of the total electric-power generation by public and private utility plants in that year.

In 1920 hydroelectric generation by utilities was about 40 percent of the total, the other 60 percent being generated by thermal power plants.

In 1950, industrial establishments producing electric energy for their own use accounted for only about 1,000,000 kw of water-power capacity and about 5 billion kwhr of water-power generation.

Important Role of Thermal Power

Availability of electric power is becoming increasingly dependent upon thermal generation. It is interesting to note that the Tennessee Valley Authority, which started out as a water-power project, now has 3,144,050 kw of steam-plant capacity, either in service or planned to be in operation by 1954. By that time its installed water-power capacity is planned to amount to 2,656,900 kw, or nearly 500,000 kw less than its steam-power capacity.

In 1920, the Federal Government generated less than one-half of one percent of the central-station water power produced in this country. By 1950, it generated about 40 percent of the central-station water power. If we include cooperatives, power districts and state projects, these figures become somewhat less than 1 percent in 1920 and 43 percent in 1950. If we include municipal electric utilities in the figures, we have 4.5 percent of all water power generated by government-owned plants in 1920 and 47.3 percent in 1950.

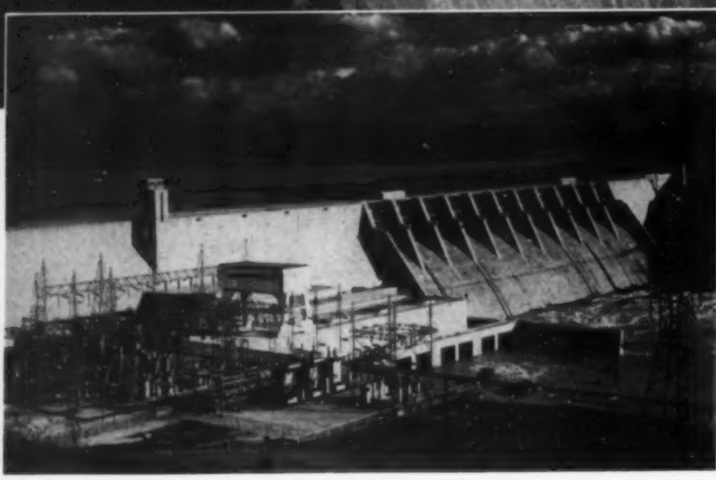
The government or publicly owned water-power plant capacity amounted to about 5.2 percent in 1920 and 45.4 percent of the total central-station water-power plant capacity developed in this country in 1950.

The *Electrical World News Issue* of March 3, 1952, published data which show to what extent the Federal Government has entered the field of water-power development and control under management of the Interior Department. Table IV is a compilation of these published data.

This compilation of historical data concerning our water power use and resources during the past century is based on a large mass of information from many sources, some of which is necessarily approximate, including the writer's personal experience during the last half of this period.

It would be too burdensome to credit all sources of information in detail. Much material published by various government and private agencies is available but the most useful and reliable information on developed water power, especially covering the earlier part of the 100-year period, is available from the U. S. Census Reports. A special water-power Census Report was prepared for 1880, which is a classic and should be studied by all interested in the history of water power in the United States.

(This article was prepared from the paper presented by Mr. Uhl before the Power Division session presided over by Byron McCoy, chairman of the Division's Executive Committee, at the Centennial Convention in Chicago.)



Left: DOUGLAS DAM • Above: NORRIS DAM

Trend

In this article a multipurpose development is taken to mean a water control project, or a system of projects, serving two or more primary purposes, one of which is the production of hydroelectric power. A purpose will be considered primary only when it is one for which the project was authorized or constructed, or when it otherwise has become a substantial paying partner in the enterprise.

The trend toward multipurpose projects will be traced through the historical development of various purposes, in connection with both technological advancement and statutory influence. No attempt will be made to establish firsts among multipurpose projects. Rather, representative projects will be cited to illustrate various phases of development—projects which are widely known and which, in their time, were of major importance.

Canals Supply Navigation and Power

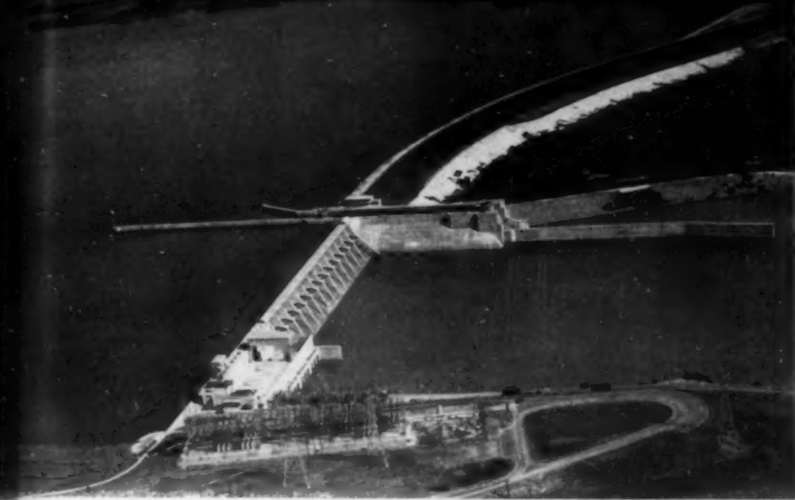
It is believed that, within the foregoing limitations, the first significant multipurpose developments were the early canals which antedated the railroads. These waterways furnished water for power development as well as for navigation. Head was created at the diversion dams built along the streams for diverting feed water, at the lock sites, and at points where water could be returned from the canal to the stream with considerable fall. Such power sites were in great demand by early manufacturers on the frontier and were the nucleus of many large industrial centers.

The late Arthur T. Safford, M. ASCE, Engineer for the Proprietors of Locks and Canals on the Merrimack Canal, has stated:

> The Proprietors of Locks and Canals on the Merrimack River were incorporated in 1792 for the purpose of making the stream navigable from tidewater to the New Hampshire line. The development of the water power available at Pawtucket Falls, in Lowell, Massachusetts, was commenced by the Proprietors in 1821....

JAMES S. BOWMAN, M. ASCE

Chief Water Control Planning Engineer, TVA
Knoxville, Tenn.



FORT LOUDOUN DAM

Norris Dam, on Clinch River, was first dam built by TVA. It was authorized in original 1933 TVA Act as multipurpose structure. Nine multipurpose dams on tributaries of Tennessee River have since been completed. Among them are three pictured here: Douglas Dam on French Broad, seen with water being spilled through discharge conduits to preserve storage capacity reserved for flood control; Fort Loudoun near head of Tennessee River; and Kentucky Dam near mouth of Tennessee River. Photo of latter shows navigation lock, powerhouse, and 16 ft of storage capacity permanently reserved for flood control.

KENTUCKY DAM

toward multipurpose developments

With the movement away from the Atlantic Seaboard, many of the new states built canals to supplement the rivers as a more stable means of transportation to the interior. Power leases at strategic points along these canals proved an important source of revenue to the growing commonwealths. During the two decades from 1825 to 1845, prosperous manufacturing communities sprang up around these sites. Isolated sections of the old canals can still be found, supplying water for the power rights, almost a century after the last canal boat disappeared.

It is interesting to note that much of the early development of hydraulic turbines in America was contemporary with the development of power sites along the old canals. Many of the early inventors did their work on turbines along the Merrimack River or along other waterways near the seaboard. Farther west in Ohio, small ironworks along the early canals, licensed under the patents of the eastern inventors, built turbines to supply the local need. A number of these became prominent in the field of hydraulic turbine design and manufacture.

Irrigation Becomes a Primary Purpose

For almost a century after the beginning of the canals, there seem to have been no other multipurpose developments than those for navigation and power. However, with the passage of the Reclamation Act in 1902, irrigation became a primary purpose. Dams and reservoirs of considerable size were built for the storage of irrigation water, with appurtenant hydroelectric plants to develop power from the water released during the irrigation season. This power was used for lifting the same water into high-level canal systems and for other project purposes.

Roosevelt Dam on the Salt River in Arizona and Shoshone Dam on the Shoshone River in Wyoming, built between 1906 and 1911, are prominent examples of such construction. During this period and in later years, many multipurpose irrigation and power projects were completed by the U. S. Reclamation Service and its successor, the U.S. Bureau of Reclamation.

During the early years of the same period in California, the City of Los Angeles built the aqueduct from Owens Valley primarily to provide

a domestic water supply but also to supply water for municipal power generation and minor irrigation. Later, in 1914, the City of San Francisco began the Hetch Hetchy project to supply water and industrial power to the San Francisco area. The initial phases of this project were substantially completed by 1924. Both projects were paid for almost entirely by municipal bond issues.

Contemporary with the construction of the early projects of the Reclamation Service for the combined purposes of irrigation and power, several projects for navigation and power were built on navigable streams by power companies under special federal legislation and under the supervision of the War Department. However, in these instances, the power companies were required to build not only the dams and power facilities but also the major part of the locks at their own expense, in return for long-time leases of the power rights. The Hales Bar project on the Tennessee River (1905–1913) and the Keokuk project on the Mississippi River at Des Moines Rapids (1910–1913) are examples of this procedure.

Twenty years later the procedure changed to the extent that the Army Engineers constructed the locks and dams on navigable streams and power companies provided the power facilities at the dams under license from the Federal Power Commission. A license fee for use of the power privilege was also fixed by the Commission. This practice was followed at the Winfield, Marmet and London dams on the Kanawha River, completed between 1934 and 1937. The principle involved was in fact a reversion to that in use when the states built the early navigation canals.

From this time on, the influence of national legislation became more and more evident in establishing the broad basis for multipurpose development. Apparently, the first definite move in this direction was in the authorization by Congress of the so-called "308 Reports." Section 3 of the River and Harbor Act, approved March 3, 1925, reads as follows:

> Sec. 3. The Secretary of War, through the Corps of Engineers of the United States Army, and the Federal Power Commission are jointly hereby authorized and directed to prepare and submit to Congress an estimate of the cost of making such examinations, surveys, or other investigations as, in their opinion, may be required of those navigable streams of the United States, and their tributaries, where power development appears feasible and practicable, with a view to the formulation of general plans for the most effective improvement of such streams for the purposes of navigation and the prosecution of such improvement in combination with the most efficient development of the potential water power, the control of floods, and the needs of irrigation: *Provided*, That no consideration of the Colorado River and its problems shall be included in the consideration or estimate provided herein.

On April 12, 1926, in response to the foregoing section, the Secretary of War, Dwight F. Davis, submitted House Document No. 308 to Congress. This report presented an estimate of the cost of examinations and surveys of about 200 rivers. Section 1 of the River and Harbor Act, approved on January 21, 1927, authorized the survey of the streams, recommended in House Document 308, together with several others. It should be noted that although none of these acts authorized construction of projects on these streams, the multipurpose idea stands forth very clearly.

Government Sponsors Flood Control

Following the great flood of 1927 in the Lower Mississippi Basin, the various Flood Control Acts of 1928 recognized the responsibility of the Federal Government to protect communities from damage by floods and ultimately opened the way for construction, by the Federal Government, of great flood control works with multipurpose features.

The signing of the Boulder Canyon Project Act on December 15, 1928, authorized the first of the great federal multipurpose projects. This project on the Colorado River, in the southwestern part of the United States, was to be constructed for the purposes of river regulation, navigation, flood control, and irrigation. It is believed that this was the first time that flood control was recognized as a definite purpose. In the original authorization, no allocation of cost was made to flood control. The entire cost of the project was to be amortized, with interest, out of the revenues from the sale of water and power. However, in 1940, Congress allocated the sum of $25,000,000 to flood control, repayable after 1987 following the amortization of the cost of the power and irrigation features. This allocation was accompanied by a reduction in the rates for water sold for power generation.

The principle that the Federal Government be reimbursed for flood control, introduced in the Boulder Canyon Project Act, prevailed for a number of years on projects where flood control was involved. Then the statute was changed so that the Federal Government would build the structures, provided that local interests would furnish the reservoir lands and land rights and make the necessary relocations. In 1938 the law was again liberalized by Congress and since then the Federal Government has borne the entire cost of reservoir projects, with no reimbursement for the cost allocated to flood control.

Section 4 of the Flood Control Act, approved June 28, 1938, authorized certain flood control and river and harbor projects to be prosecuted under the direction of the Secretary of War and the supervision of the Chief of Engineers. This act, and practically all such acts since that time, further provided:

> That penstocks and similar facilities adapted to possible future use in the development of hydroelectric power shall be installed in any dam herein authorized when approved by the Secretary of War upon recommendation of the Chief of Engineers and of the Federal Power Commission.

This statute gave great impetus to the inclusion of flood control in multipurpose projects. Thus, since the government had also assumed responsibility for the entire cost of flood control reservoirs, the many projects of the Army Engineers in which flood control and power are combined originated with the Flood Control Act of 1938. The first recommendation by the Federal Power Commission, under this act, was for the installation of a penstock in the proposed Knightville Dam on the Westfield River in Massachusetts, on December 3, 1938. Since that time the Commission has recommended the installation of penstocks in some 60 dams.

TVA Extends Multipurpose Concept

The Tennessee Valley Authority Act, approved in May 1933, actually applied for the first time, as far as is known, the multipurpose concept to the development and utilization of the water resources of an entire river basin. The multipurpose feature is implicit in the act which gives the power to:

> . . . construct such dams and reservoirs, in the Tennessee River and its tributaries, as . . . will provide a nine-foot channel in said river and maintain a water supply for the same, from Knoxville to its mouth, and will best serve to promote navigation on the Tennessee River and its tributaries and control destructive flood waters in the Tennessee and Mississippi River drainage basins; and . . . acquire and construct powerhouses, power structures, transmission lines, navi-

gation projects, and incidental works in the Tennessee River and its tributaries . . . The directors of the Authority are hereby directed to report to Congress their recommendations not later than April 1, 1936, for the unified development of the Tennessee River system.

Norris Dam, the first built by TVA, was authorized in the original act as a multipurpose structure. Since then seven multipurpose dams on the Tennessee River have been constructed, completing the 9-ft channel from the mouth to Knoxville. Nine multipurpose dams on the tributaries have been completed and are in operation. Because of World War II, some of the projects were undertaken much sooner than had been anticipated in the 1936 Report.

For more than 25 years, beginning with the authorization of the "308 Reports," Congress appears to have adopted the multipurpose project as a desirable means of developing and conserving the water resources of the United States. However, the methods of operating such projects, the extent of reimbursement of the Federal Government, and the distribution of the benefits have become subjects of acrimonious debate. To date these arguments have not obscured the fact that a nation faced with serious water shortages in many of its important regions can ill afford to conserve water for one purpose and at the same time neglect its possible economical utilization for other purposes.

Role of Federal Government

The construction and operation of major navigation, flood control, and irrigation projects seem to be no longer questioned as legitimate functions of the Federal Government. Such objections as have been made to specific projects for any or all of these three purposes appear to stem from the idea that if the projects are not built there will be no opportunity for including power facilities. The specific objection to the generation of hydroelectric power seems to center mainly about methods of transmitting and distributing output.

Discussion of all questions may throw light on the future trend in multipurpose development. It is probably true that some federal multipurpose projects have been built, which, because of meager data or overenthusiasm, were undertaken when they should not have been. On the other hand, it is not necessary to burn the barn to get rid of the rats. Although changes in policies may be expected from time to time, the intent of Congress with respect to water conservation is too clear to encourage the belief that it can be persuaded to stifle meritorious projects by enacting legislation to impose far more rigid tests of economic justification, for instance, than those applied customarily to either public or private work. Farm ponds and improved land-use practices are very good in themselves. However, recent attempts to substitute these for major flood control reservoirs, thus eliminating the opportunity for multipurpose projects, can lead only to disillusionment and disaster in downstream areas when flood producing storms occur. The large reservoir is the only dependable means of reducing flood stages on many areas.

The present practices of federal agencies with respect to authorization, justification, reimbursement, allocation, and other phases of multipurpose projects are extremely diverse. Congress has authorized projects without much thought of uniformity of policy and, in fact, has drifted away from uniformity by frequent amendment of the basic acts to conform to the demands of local groups. The appointment of the President's National Water Resources Policy Commission was recognition of the confusion that exists. However, the chances for remedial legislation in the near future do not seem to be hopeful. The recommendations of the Water Resources Committee in the mid-thirties merited much attention but received little.

Nevertheless the enactment of a sound, fair, and consistent national water policy should eliminate much of the suspicion and misunderstanding that now exist as to the importance of multipurpose development in conservation of the water resources of the United States.

The trend of multipurpose projects in recent years should afford some indication of future trends. Accordingly, the data given in Table I have been prepared to show the multipurpose projects completed between 1921 and 1950, inclusive, by five-year periods. The projects are further classified as to the agency that financed the construction.

It will be observed that in these three decades 69 major multipurpose projects have been completed. In the first half of this period there were 17; in the last half, 52. In the first half 6 were built wholly with federal funds, except for power plants at two dams, and 11 were built by municipalities, irrigation districts, and other local bodies. In the second half, 46 were built wholly with federal funds, except for the power station at one dam; four others were jointly financed by the Federal Government and by local agencies; and only two were built entirely by local financing.

TABLE I.

Multipurpose Projects Involving Hydroelectric Power Completed Between 1921 and 1950, Inclusive

Period	Total Projects	Means of Financing: Federal	Loan-Grant	Private
1921–1925	6	3	. .	3
1926–1930	7	1	. .	6
1931–1935	4	2	. .	2
1936–1940	15	13	1	1
1941–1945	18	14	3	1
1946–1950	19	19	. .	. .
Totals . .	69	52	4	13

A comparison of the number of federal multipurpose projects involving electric power and financed by federal funds since 1933 shows that in 1946 there were 33 such projects completed and in service. In 1952 there were 52 projects in service, an increase of 19 in six years. In 1946, 28 projects were under construction, while in 1952 there were 34.

The approved and authorized federal multipurpose projects on which no work has been started total 95 at this time.

These data seem to indicate that the multipurpose water control project has been rather widely accepted and will probably continue to be the appropriate means of developing water resources where this type of project is needed and is economically justified. The number of such projects now in operation should afford opportunity for careful examination of the engineering soundness of such projects based on facts rather than on speculation.

The proposition of whether the Federal Government should continue to dominate such projects will undoubtedly undergo some changes as time goes on. The number of those now authorized for federal construction is almost twice as many as have been completed in the last twenty years and more than the total of those now in service and under construction. Hence, it is probably safe to predict that present trends will persist for some time to come.

(This article is based on the paper presented by Mr. Bowman before a Power Division session presided over by Byron O. McCoy, chairman of the Division's Executive Committee, at the Centennial Convention in Chicago.)

CARL H. GIROUX, Special Assistant, Office of the Chief of Engineers, Department of the Army, Washington, D.C.

Modern hydraulic dredging—a product of experience

Moving dirt from one place to another is one of the oldest tasks of the human race and the means of accomplishment have taken various forms. The one to be considered here is the hydraulic method. Probably the first reference to such a method is found in Greek mythology where it is stated that the Augean Stables were cleaned by diversion of the Alpheus and Peneus rivers. The equipment used for this Herculean feat is not disclosed but it is safe to say that had a modern dredge been available the project could have been completed even more expeditiously than the story relates.

However, it is not the intent of this article to deal with mythology or ancient history, but to give the reader a glimpse of early efforts in underwater dredging as it is now known, and then to show what has been accomplished in developing modern tools for this purpose. The article will be further confined to accomplishments in the United States, as the equipment developed abroad, while differing somewhat in detail, does not exceed in performance that produced in our own country.

The early history of hydraulic dredging in the United States largely revolves around the activities of the Corps of Engineers, which since 1824 has been concerned with the improvement of rivers and harbors for navigation. This work involved three major classifications of conditions each presenting its own problems, with a decided effect on the types of equipment that can be used.

Seagoing Hopper Dredges

The first classification to be discussed is the initial dredging and maintenance of deep-water channels in harbors abutting on the open sea. Here continuous operation without serious interference with traffic and in spite of adverse weather conditions is the problem. Obviously any piece of equipment which is anchored in the channel is a menace to navigation, and in case of high seas is difficult to operate. Then there is the problem of disposing of the dredged material. Pumping ashore requires further obstruction of the navigable waters, and the use of barges and tugs adds to the confusion.

As early as 1855 the idea of using a self-propelled and self-contained dredge was born. After a number of experimental vessels had been tried, with varying degrees of success, the Corps of Engineers in 1891 built the *Charleston*, the first specially designed sea-going hopper dredge. Although it had a capacity of only about 300 cu yd, it incorporated most of the essential elements in use today. It was self-propelled, could dredge while under way, and had integral hoppers with bottom-dump doors. The details of design and the record of performance of this dredge are of little importance at this time, but it is significant that the same type of dredge is still in use.

At the time the *Charleston* was built, and for many years thereafter, efficiency was a secondary consideration, the main problem being to find a device that could physically remove and dispose of the material. The low cost of construction, cheap labor, proximity of disposal areas, all tended to minimize the importance of output and cost of operation. At that time, the low-pressure reciprocating steam engine was the only prime mover available and was used for propelling the vessel, driving the pumps and winches, and for all auxiliary purposes. Coal was the fuel.

As time went on there were changes not only in the type of equipment available, but also in the conditions of operation. The first significant change in motive power was the introduction of the diesel engine, which for moderate power showed a marked improvement in weight, space, and fuel economy. A contemporaneous development was the growing use of electrical equipment in marine service. Consequently, in 1922, the Corps of Engineers decided to use diesel-electric drive on four 1,250-cu yd dredges which had been originally designed for steam-reciprocating machinery. The performance of these dredges has been outstanding; two of them are still in service and the others would be if it were not for the change in dredging conditions.

Importance of Efficiency Recognized

As deeper and more extensive channels within our major harbors were required, and the distances to disposal areas increased, the effectiveness of the small, slow and somewhat inefficient dredges decreased. It became apparent that if the work was to be done quickly and at a reasonable cost, new equipment must be provided. During the steam-engine era a number of dredges were built having hopper capacities of approximately 3,000 cu yd and one as high as 4,000 cu yd, but the running speed was low and fuel consumption high.

As these vessels neared the end of their economic life, the Corps initiated a program for replacement, utilizing the experience gained from the operation of the older dredges and taking advantage of the latest improvements in motive power. This program culminated in the design and construction of the *Essayons*, which reflects the latest thinking in large seagoing hopper dredges. Of course, there still remains a field for small dredges of this type, with light draft for use in minor harbors. Those constructed in recent years and those contemplated for the future have or will have many of the basic features of the *Essayons*.

The *Essayons* has an overall length of 525 ft, a beam of 72 ft, a light draft of 20 ft, a fully loaded draft of 29 ft, and a hopper capacity of 8,000 cu yd. It has a speed of 17 miles per hour light, and 16 miles per hour fully loaded. The propulsion power is 4,000 hp on each of the two screws, and the dredging power is 1,850 hp on each of the two pumps. A full de-

cription of this dredge can be found in other literature but a few of the features which were adopted after many years of experience should be mentioned.

Maneuverability is paramount in a seagoing hopper dredge even when running at slow speed during dredging, and therefore twin screws are essential. It is also necessary to run each screw independently throughout its complete range of speed from full ahead to full astern in order to keep the vessel on its course and to turn it sharply. For this purpose, the electric drive controlled from the pilot house has proved to be the best solution and is used on the *Essayons*.

Some of the first dredges of this type were equipped with a single drag arm suspended from the stern, and others had a similar drag arm located about amidships in a well on the fore and aft center line. These designs had the disadvantages of not being able to dredge close to a bank and of using valuable space within the ship's structure. The scheme of using two drag arms, one pivoted from each outboard side of the dredge, has been found to be the best arrangement for the majority of conditions. It does introduce, however, appendages which are vulnerable when docking and in case of collision and which offer considerable resistance when the ship is running at full speed in a loaded condition. To overcome these disadvantages, on the *Essayons* the arms are pivoted from sliding trunnion plates and can be raised clear of the side of the vessel when the dredging equipment is not in operation.

Solids Retention, a Difficult Problem

One of the most difficult problems to solve in connection with this type of hydraulic dredging, is the retention of solids in the hoppers, particularly when the material is light and slow to settle. Many experiments and different arrangements of hoppers, discharge pipes, overflows, and baffles have been tried. No one scheme has been found ideal for different sizes of hoppers and for the various kinds of material which a dredge is required to handle. The idea is to dissipate the energy in the discharge from the pump as quickly as possible, to eliminate turbulence, and to provide as long a path as feasible to the overflow weirs so that the material will have an opportunity to settle out of the mixture, fill the hoppers, and permit water only to pass overboard. The arrangement adopted for the *Essayons* and other dredges built in the last few years gives good results but there is still room for improvement.

Allied to this problem of retaining material in the hoppers is that of continuously dredging a mixture of high solid content and keeping the surplus water to a minimum. This is not so serious when dredging sand, which settles readily, but where silt or soft mud is encountered there is great difficulty in preventing the suction from choking if the drag is too deeply submerged. When this occurs it is necessary to raise the drag and pump water only until the choke is cleared, an operation which tends to wash overboard some of the material already in the hoppers. For this reason, modern drags have been equipped with auxiliary openings on the upper side which can be adjusted for the specific conditions so as to give the greatest practicable percentage of solids without choking the pump. This arrangement works fairly well but does not completely overcome the difficulty.

A few years ago a young engineer, Richard Hoffman, employed by the New York District of the Corps of Engineers, became interested in this problem and observed carefully the conditions under which the choking action took place. He found that it was not always a case of deep submersion of the drag or of too dense a mixture. He finally concluded that, in this particular locality, the entrained gas had some effect. Such gas was liberated under the vacuum created by the dredging pump and the pump would become air or gas bound.

Acting on this theory, gas ejectors were installed on the suction side of one of the dredging pumps whereby any accumulation of gas was immediately removed. The results were at once apparent and it was found that a much more concentrated mixture could be maintained than formerly. As a consequence, all the present hopper dredges of the Corps of Engineers which are called upon to handle mud with entrained gases are equipped with gas ejectors or pumps, and the output under these conditions has been remarkably improved. Such a system is also applicable to any other suction dredge where gas is present in the material to be dredged.

A word should be said here about a very important adjunct of the seagoing hopper dredge—the suction drag. All sorts of devices have been tried with the view of increasing the percentage of material entering the suction pipe. These have included drags of various sizes, shapes and weights, plain and with teeth, ridges, disks, and other types of scarifiers. The most satisfactory drag for general conditions is a shoe type, articulated so as to be self-adjusting to the depth and contour of the bottom and having an abrasion-resisting grid on the under side. Special drags are used for dredging coral and for banks having steep side slopes and other unusual characteristics.

Many improvements have been made in dredging pumps since the first ones, designed primarily for water, were used. Particularly the shape of the vanes to prevent clogging, and the design and types of material used for various parts to resist abrasion, have been given a great deal of consideration.

Seagoing hopper dredge *Essayons* reflects latest thinking in design of this class of dredge. Although this particular dredge is large—525 ft long with 29-ft draft fully loaded—there is a field for small dredges of this type to operate in minor harbors.

CARL H. GIROUX, Special Assistant, Office of the Chief of Engineers, Department of the Army, Washington, D.C.

Modern hydraulic dredging—a product of experience

Moving dirt from one place to another is one of the oldest tasks of the human race and the means of accomplishment have taken various forms. The one to be considered here is the hydraulic method. Probably the first reference to such a method is found in Greek mythology where it is stated that the Augean Stables were cleaned by diversion of the Alpheus and Peneus rivers. The equipment used for this Herculean feat is not disclosed but it is safe to say that had a modern dredge been available the project could have been completed even more expeditiously than the story relates.

However, it is not the intent of this article to deal with mythology or ancient history, but to give the reader a glimpse of early efforts in underwater dredging as it is now known, and then to show what has been accomplished in developing modern tools for this purpose. The article will be further confined to accomplishments in the United States, as the equipment developed abroad, while differing somewhat in detail, does not exceed in performance that produced in our own country.

The early history of hydraulic dredging in the United States largely revolves around the activities of the Corps of Engineers, which since 1824 has been concerned with the improvement of rivers and harbors for navigation. This work involved three major classifications of conditions each presenting its own problems, with a decided effect on the types of equipment that can be used.

Seagoing Hopper Dredges

The first classification to be discussed is the initial dredging and maintenance of deep-water channels in harbors abutting on the open sea. Here continuous operation without serious interference with traffic and in spite of adverse weather conditions is the problem. Obviously any piece of equipment which is anchored in the channel is a menace to navigation, and in case of high seas is difficult to operate. Then there is the problem of disposing of the dredged material. Pumping ashore requires further obstruction of the navigable waters, and the use of barges and tugs adds to the confusion.

As early as 1855 the idea of using a self-propelled and self-contained dredge was born. After a number of experimental vessels had been tried, with varying degrees of success, the Corps of Engineers in 1891 built the *Charleston*, the first specially designed sea-going hopper dredge. Although it had a capacity of only about 300 cu yd, it incorporated most of the essential elements in use today. It was self-propelled, could dredge while under way, and had integral hoppers with bottom-dump doors. The details of design and the record of performance of this dredge are of little importance at this time, but it is significant that the same type of dredge is still in use.

At the time the *Charleston* was built, and for many years thereafter, efficiency was a secondary consideration, the main problem being to find a device that could physically remove and dispose of the material. The low cost of construction, cheap labor, proximity of disposal areas, all tended to minimize the importance of output and cost of operation. At that time, the low-pressure reciprocating steam engine was the only prime mover available and was used for propelling the vessel, driving the pumps and winches, and for all auxiliary purposes. Coal was the fuel.

As time went on there were changes not only in the type of equipment available, but also in the conditions of operation. The first significant change in motive power was the introduction of the diesel engine, which for moderate power showed a marked improvement in weight, space, and fuel economy. A contemporaneous development was the growing use of electrical equipment in marine service. Consequently, in 1922, the Corps of Engineers decided to use diesel-electric drive on four 1,250-cu yd dredges which had been originally designed for steam-reciprocating machinery. The performance of these dredges has been outstanding; two of them are still in service and the others would be if it were not for the change in dredging conditions.

Importance of Efficiency Recognized

As deeper and more extensive channels within our major harbors were required, and the distances to disposal areas increased, the effectiveness of the small, slow and somewhat inefficient dredges decreased. It became apparent that if the work was to be done quickly and at a reasonable cost, new equipment must be provided. During the steam-engine era a number of dredges were built having hopper capacities of approximately 3,000 cu yd and one as high as 4,000 cu yd, but the running speed was low and fuel consumption high.

As these vessels neared the end of their economic life, the Corps initiated a program for replacement, utilizing the experience gained from the operation of the older dredges and taking advantage of the latest improvements in motive power. This program culminated in the design and construction of the *Essayons*, which reflects the latest thinking in large seagoing hopper dredges. Of course, there still remains a field for small dredges of this type, with light draft for use in minor harbors. Those constructed in recent years and those contemplated for the future have or will have many of the basic features of the *Essayons*.

The *Essayons* has an overall length of 525 ft, a beam of 72 ft, a light draft of 20 ft, a fully loaded draft of 29 ft, and a hopper capacity of 8,000 cu yd. It has a speed of 17 miles per hour light, and 16 miles per hour fully loaded. The propulsion power is 4,000 hp on each of the two screws, and the dredging power is 1,850 hp on each of the two pumps. A full de-

scription of this dredge can be found in other literature but a few of the features which were adopted after many years of experience should be mentioned.

Maneuverability is paramount in a seagoing hopper dredge even when running at slow speed during dredging, and therefore twin screws are essential. It is also necessary to run each screw independently throughout its complete range of speed from full ahead to full astern in order to keep the vessel on its course and to turn it sharply. For this purpose, the electric drive controlled from the pilot house has proved to be the best solution and is used on the *Essayons*.

Some of the first dredges of this type were equipped with a single drag arm suspended from the stern, and others had a similar drag arm located about amidships in a well on the fore and aft center line. These designs had the disadvantages of not being able to dredge close to a bank and of using valuable space within the ship's structure. The scheme of using two drag arms, one pivoted from each outboard side of the dredge, has been found to be the best arrangement for the majority of conditions. It does introduce, however, appendages which are vulnerable when docking and in case of collision and which offer considerable resistance when the ship is running at full speed in a loaded condition. To overcome these disadvantages, on the *Essayons* the arms are pivoted from sliding trunnion plates and can be raised clear of the side of the vessel when the dredging equipment is not in operation.

Solids Retention, a Difficult Problem

One of the most difficult problems to solve in connection with this type of hydraulic dredging, is the retention of solids in the hoppers, particularly when the material is light and slow to settle. Many experiments and different arrangements of hoppers, discharge pipes, overflows, and baffles have been tried. No one scheme has been found ideal for different sizes of hoppers and for the various kinds of material which a dredge is required to handle. The idea is to dissipate the energy in the discharge from the pump as quickly as possible, to eliminate turbulence, and to provide as long a path as feasible to the overflow weirs so that the material will have an opportunity to settle out of the mixture, fill the hoppers, and permit water only to pass overboard. The arrangement adopted for the *Essayons* and other dredges built in the last few years gives good results but there is still room for improvement.

Allied to this problem of retaining material in the hoppers is that of continuously dredging a mixture of high solid content and keeping the surplus water to a minimum. This is not so serious when dredging sand, which settles readily, but where silt or soft mud is encountered there is great difficulty in preventing the suction from choking if the drag is too deeply submerged. When this occurs it is necessary to raise the drag and pump water only until the choke is cleared, an operation which tends to wash overboard some of the material already in the hoppers. For this reason, modern drags have been equipped with auxiliary openings on the upper side which can be adjusted for the specific conditions so as to give the greatest practicable percentage of solids without choking the pump. This arrangement works fairly well but does not completely overcome the difficulty.

A few years ago a young engineer, Richard Hoffman, employed by the New York District of the Corps of Engineers, became interested in this problem and observed carefully the conditions under which the choking action took place. He found that it was not always a case of deep submersion of the drag or of too dense a mixture. He finally concluded that, in this particular locality, the entrained gas had some effect. Such gas was liberated under the vacuum created by the dredging pump and the pump would become air or gas bound.

Acting on this theory, gas ejectors were installed on the suction side of one of the dredging pumps whereby any accumulation of gas was immediately removed. The results were at once apparent and it was found that a much more concentrated mixture could be maintained than formerly. As a consequence, all the present hopper dredges of the Corps of Engineers which are called upon to handle mud with entrained gases are equipped with gas ejectors or pumps, and the output under these conditions has been remarkably improved. Such a system is also applicable to any other suction dredge where gas is present in the material to be dredged.

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As the costs of construction, operation, and maintenance of seagoing hopper dredges have risen, it has become imperative that more hours of operation per year be attained than formerly in order to keep the cost of removing the material to a reasonable figure. Therefore, provision is now being made to quarter and feed a crew for continuous operation and to provide recreational facilities, comfortable accommodations, and conveniences to maintain a high morale among the crew members. Also navigational aids such as radio-telephone, radar, radio direction finders, gyro compass, and fathometers have become standard equipment so as to permit continued operation during adverse weather conditions.

The matter of safety has not been overlooked in designing modern seagoing dredges. Since these vessels must work in congested waterways, collisions are bound to occur, with danger of complete loss of the dredge and sometimes loss of life. To minimize these hazards, the safety requirements of the U.S. Coast Guard and the American Bureau of Shipping are observed, and the hulls are so designed that any two compartments may be flooded without sinking of the dredge, even when fully loaded.

As an indication of the improvement in performance that has been gained by increasing the hopper capacity and the speed of travel it should be mentioned that the *Essayons* has attained a monthly output of over 500,000 cu yd when operating at a distance from the disposal area of 25 miles, and an output as high as 1,500,000 cu yd per month with a haul of 3 miles. In comparison, one of the older dredges, with a hopper capacity of 2,500 cu yd, had an output of less than 100,000 cu yd and 250,000 cu yd, respectively, under the same conditions.

Dustpan Dredges on Inland Waterways

The second classification of conditions suitable for hydraulic dredging is that pertaining to inland waterways, particularly the Mississippi and its tributaries. Here the problem is to maintain a channel of sufficient depth and width to accommodate packet and barge traffic. On these streams the integrity of the channel is continually jeopardized by deposits of silt and sand wherever slack water occurs. This is particularly true during subsidence from a period of high water, when sand bars form very rapidly, many of them of considerable proportions. Much improvement has been made in the original channel conditions by building contraction works to confine and speed up the flow, by cutoffs in the bends to increase the hydraulic gradient, and by bank revetment to keep the channels in proper alignment and reduce the amount of entrained material. In spite of these efforts, large quantities of sediment continue to be deposited and must be removed by hydraulic dredges.

In streams of this character, where the quantity of dredged material is small compared to the amount carried by the river, it is not considered necessary to remove material permanently from the river bed, but merely to put it back into the water, where it will be carried away and dropped at some unobjectionable point. This method has given rise to the trial of many kinds of agitators which merely stir up the deposits with the hope that they will be carried away without further help. Although some of these experiments have met with a small measure of success, a type of hydraulic dredge developed particularly for this use has proved to be the most efficient. This is known as the dustpan dredge.

As a result of earlier experiments with hydraulic dredging, the Mississippi River Commission in 1893 built the *Alpha*, which incorporated most of the features of the present dustpan dredge. A complete description and plan of this dredge appeared in the ASCE *Transactions* for 1898 (vol. 40, p. 215). A few of the salient features are described below.

The hull was of wood about 140 ft long with a draft of 4 ft. Two types of dredging machinery were installed, one at each end of the vessel. One had a suction pipe with water jet agitator, and the other had no agitator but was constructed in the form of a scraper. Subsequently the scraper was discarded and the suction with the jet agitator retained. This principle has been found to be simple and effective, and is used universally on dredges of this type today.

Disposal of Dredged Material

Another feature developed in early experiments which is still in use, is the means for disposing of the dredged material. It was found that discharge directly at the dredge did not suffice, but that if the material could be deposited only a short distance away, most of it would either be carried off or redeposited where it would do no harm to the channel. A short floating pipeline was devised for this purpose, with joints flanged and articulated at the dredge. Such a line, when water is pumped through it, tends to straighten out, but it must be controlled so as to discharge at the most advantageous point. To accomplish this, an adjustable baffle plate is placed at the end of the discharge pipe. The water, impinging on this baffle, creates a reaction sufficient to move the pipeline even against the current, and thereby permits spotting of the discharge point quite accurately. When the pump is stopped, the pipeline floats with the current and lies parallel to the dredge out of the way of traffic, permitting easy movement of the dredge.

The first dustpan dredges had to be towed to and from the site. Eventually propelling machinery was added so that the dredges were independent of attendant plant. The propelling equipment consisted of stern or side paddle wheels where extremely shallow draft was required, and tunnel screws where more draft was permissible.

In the earlier dredges the suction heads were of various forms, some being equipped with mechanical devices for loosening the material. Such devices were discarded rather quickly, however, as it was found that high-pressure water jets did the job effectively and the equipment was less costly to manufacture and maintain. On adoption of the water-jet principle of agitation, the tendency was to flatten and widen the suction head so that it truly resembled a dustpan and gave rise to the name by which this type of dredge is now known.

About 1930 the Mississippi fleet of dredges had nearly reached the end of its economic life, and increasing traffic on the lower Mississippi and on the Missouri necessitated the construction of more and larger dredges for the rapid removal of channel obstructions. Experience gained over a long period of years clearly indicated that the dustpan type of hydraulic dredge was the most suitable. Between 1932 and 1934, nine dredges of this type were built with pumping power ranging from 1,000 to 2,100 hp. All are self-propelled; one has a stern paddle wheel; four have side paddle wheels; and four have tunnel screws. Those with paddle wheels, designed to operate in the upper Mississippi and Missouri rivers, have a draft of less than 5 ft, while those with tunnel screws, designed for the lower Mississippi River, have a draft of over 6 ft.

Representative of the largest and most modern of existing dustpan dredges is the *Jadwin*, which is 250 ft long, has a beam of 52 ft, and a draft in working condition of about 6½ ft. The suction head is 32 ft

Dustpan dredges were developed for use on inland waterways, particularly Mississippi and its tributaries. Purpose is to maintain channels of sufficient depth to accommodate packet and barge traffic. Dredge type derives name from wide flat shape of suction head. Dredge shown is *Jadwin*.

wide and has 34 nozzles for agitation, passing 11,000 gal of water per minute. The dredging pump has a runner 80 in. in diameter, and a suction pipe and discharge pipe 34 and 32 in. in diameter respectively. It is driven through reduction gears by a 2,100-hp steam turbine. The vessel is propelled by two triple-expansion steam engines, each rated about 1,000 hp, driving twin screw propellers. The free-running speed of the vessel is approximately 9½ miles per hour.

When dredging at a depth of 20 to 30 ft below the water surface, and with about 800 ft of floating pipeline, this dredge will excavate at least 3,000 cu yd per hour. With a 12-ft bank of sand ahead, its rate of advance is approximately 3 ft per minute. The velocity in the pipeline is about 20 fps. This may be compared to the *Alpha*, which had a pumping power of about 300 hp and excavated less than 500 cu yd per hour under similar conditions.

Cutterhead Pipeline Dredges Developed

The third set of conditions for which hydraulic dredges are suitable is the dredging of new channels, the deepening of old ones, and the placing of hydraulic fill for the construction of dams or the reclamation of land contiguous to waterways. For this work a type of plant known generally as the cutterhead pipeline dredge has been developed.

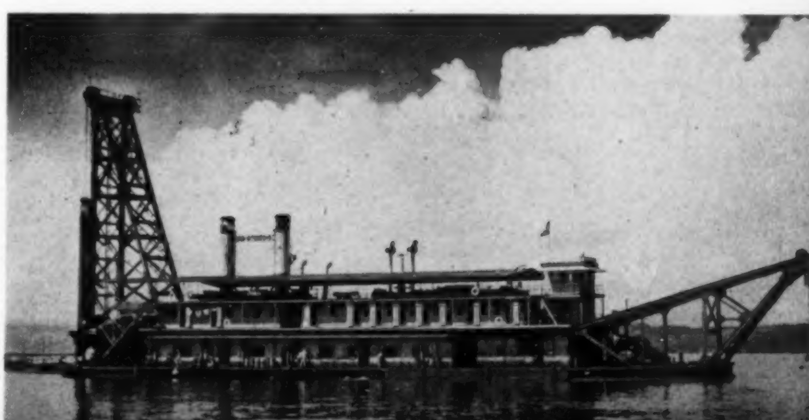
Such a dredge consists essentially of a barge-type hull, a ladder hinged at the forward end carrying the suction pipe and revolving cutter, a centrifugal pump discharging to a floating pipeline, two spuds for swinging and advancing the dredge, and necessary machinery. Such dredges are usually not self-propelled.

The early use of cutterhead dredges seems to be centered around San Francisco Bay and vicinity, where in about 1875 the need for a machine to build levees and reclaim land, using material lying beneath the water surface, resulted in the invention and development of dredges having some of the characteristics of those in use at the present time. The history of this development is long and involved, and those who are sufficiently interested will find plenty of literature on the subject, but for the purpose of this article it is sufficient to say that progress in improving the performance of such dredges has been continuous and has kept pace with modern trends in motive power and machinery. Here, as with hopper dredges, we passed through the reciprocating steam-engine era to that of the diesel engine, the steam turbine, and the widespread use of electrical apparatus. Omitting all this, some of the characteristics and accomplishments of modern cutterhead pipeline hydraulic dredges will be described.

The dredge *Mindi*, built by the Ellicott Machine Corp. for the Panama Canal, is representative of modern self-contained high-powered dredges of this type. Oil-fired boilers operating at 400 psi are used to furnish steam for the main machinery. The dredge pump, which has a 32-in. suction and 28-in. discharge, is driven through reduction gears by a steam turbine rated at 5,000 hp but capable of producing 5,500 hp under favorable conditions. A separate turbine-driven generating set furnishes power for the cutter motor, the hauling and hoisting winch motor, and other auxiliaries—all using direct current. The cutter motor is rated at 600 hp, is waterproof, forced ventilated, and drives the cutter through a self-contained speed reducer, all mounted directly on the ladder. The motor for the hauling and hoisting winch is rated at 200 hp and is also forced ventilated. The speed of both these motors is adjustable over a wide range by variable voltage control.

The *Mindi* is capable of dredging to a depth of 72 ft, and for this purpose has a ladder and spuds which are approximately 100 ft long. The output of such a dredge is of course dependent on many conditions such as the nature of the material, the length of the pipeline, the dredging depth, and operational interruptions. The *Mindi* has dredged as much as 1,500,000 cu yd in 22 days, and its peak output was 83,500 cu yd in 21 hours. This was in sand, silt, and clay with 8,000 ft of pipeline.

Where a specific project is of sufficient magnitude to warrant the construction of a special dredge and where electric power can be obtained readily at a low rate, it is sometimes



Cutterhead pipeline dredge is designed to serve triple purpose of dredging new channels, deepening old ones, and placing hydraulic fill. *Mindi*, shown at right, built by Ellicott Machine Corp., typifies modern, self-contained, high-powered dredges of this type. Dredge pump is driven by 5,000-hp steam turbine, and cutter motor is rated at 600 hp. *Mindi* is capable of dredging to depth of 72 ft and has dredged up 83,500 cu yd in 21 hours.

advantageous to omit the prime mover and use commercial power throughout. In such cases alternating current at a fairly high voltage is usually carried aboard by means of insulated portable cable. The dredge pump is commonly direct-connected to a variable-speed, wound-rotor, induction motor designed for the voltage of the supply. Power for the cutter motor and other auxiliaries may be merely transformed to a lower voltage or may be converted to direct current by motor-generator sets in order to obtain more economical or wider speed variation, as conditions may demand.

Mammoth Job at Fort Peck Dam

An outstanding example of the use of electric dredges was the construction of the Fort Peck Dam on the Missouri River under the direction of the Corps of Engineers during the years 1934 to 1939, inclusive. For this purpose, four dredging units were constructed on the site, each consisting of one cutterhead hydraulic dredge, one floating booster unit, and one booster unit mounted on railway trucks, all driven by electric power derived from the system of the Montana Power Co., nearly 300 miles away. Each dredge and each floating booster were equipped with two 28-in. pumps driven by 2,500-hp, 257-rpm, 6,600-volt induction motors. Each railway unit had one such pump. The cutter motors were rated at 700 hp, 720 rpm, 6,600 volts.

Both the dredge pump motors and the cutter motors were of the wound-rotor induction type, and the speed was controlled by liquid slip regulators connected in the secondary windings. Other auxiliaries were driven by alternating-current motors of lower voltage. Power was brought to the floating units by flexible, rubber-insulated, rubber-jacketed cable supported on floating pontoons and connected at the shore end to overhead distribution lines which were moved from time to time to keep within reasonable distance of the dredges.

As the work progressed, the booster units were shifted as required to maintain optimum velocities and pressures in the pipelines. The peak was reached in August of 1939, when the dredge *Jefferson* by means of its own two pumps and eight additional ones, pumped through 36,420 ft of pipeline with a static lift of 110 ft. Under this condition a velocity of approximately 21 fps was maintained, transporting 16 percent solids with an output averaging 2,000 cu yd per pumping hour. The energy consumed during this period was 8 kwhr per cu yd as compared with an average of about 4 kwhr for the entire job.

The period during which the Fort Peck dredges were in operation afforded an excellent opportunity to study the effect of varying pipeline velocities, cutter speeds, and other operational factors, and much valuable information was obtained. The nature of the material (sharp sand and gravel) caused rapid erosion of the pump impellers and casings, the pipelines, cutters, and other exposed parts.

Innumerable experiments were made using various abrasion-resisting materials and renewable pump liners, and varying the shape of affected parts. These experiments resulted in greatly reducing the cost of maintenance and lost time consumed in changing equipment.

At present an electric cutterhead pipeline dredge is being constructed for the Beauharnois Light, Heat and Power Co., an agency of the Quebec Hydro-Electric Commission, which far exceeds in power and capacity any similar plant built to date. This dredge is to be used to deepen and widen the forebay channel leading to the Beauharnois Power House, through cemented boulder clay which is extremely hard to remove. The dredge will receive power from shore through a flexible cable at 13,000 volts, alternating current.

The pump will be driven by an 8,000-hp, 275-rpm, wound-rotor, induction motor with an adjustable speed of 200 rpm minimum. Power for the cutter and hauling and hoisting machinery will be converted from alternating to direct current so as to utilize variable voltage control through a wide speed range. The cutter motor will be 1,000 hp and will be mounted directly on the ladder. The pump has a discharge diameter of 36 in. and is designed to pass boulders up to 28 in. in diameter. The dredge was designed by Ellicott Machine Corp. of Baltimore, Md., which is also furnishing the main items of dredging machinery, and is being built by Marine Industries at Sorell, P. Q., Canada.

It must not be inferred that all the recent advancement in cutterhead dredges has been in the matter of increasing their size and capacity. Just as much development has been accomplished on medium and small-capacity plant ranging in discharge size from 6 to 20 in., making it more efficient, lower in cost, and adaptable to a variety of work which would not justify the use of a large dredge. Diesel engines are almost universally used for such applications. In most cases the dredge pump is directly connected to a diesel engine of proper speed and power, although in some instances electric drive is employed to obtain the additional flexibility and reliability of multiple engine drive. Electric auxiliaries, either alternating currect, direct current, or a combination of both, are almost universally employed. The wide range in speed and economy of variable voltage control usually dictates direct current for the cutter and hauling machinery.

Recently an 8-in. dredge of simple design, with diesel-driven machinery, which can be dismantled and transported by railway or trailer truck, has been put on the market.

In 1946, when the means of excavating a sea-level canal across Panama was being studied, the use of cutterhead hydraulic dredges was considered for part of the work. The problem here was not only to remove an extremely large volume of material but to dredge to a depth of 135 ft below the water surface, which is far deeper than any similar project to date. While the dredges were never built, the design was carried to a point which indicated their feasibility. Aside from the unprecedented size and power of the dredging machinery, the most novel feature of this proposed design was a booster pump

Outstanding example of use of electric cutterhead pipeline dredges was on construction of Fort Peck Dam, world's largest earth dam, containing 125 million cu yd of material, most of which was dredged from river bed and pumped into place. In air view, dredges are shown in borrow area, from which material was pumped to dam, out of sight at left.

part way down the ladder to aid the main pump in overcoming the suction losses. Such losses would be so great, because of the long suction line, that otherwise there would be little head available for lifting the material.

Dredging Problems and Solutions

Progress in any field is dependent upon the continued improvement of the individual components and this has been true in the field of hydraulic dredging. In many of the early dredges, the failure of one part to do its duty often brought the whole operation to a standstill. Rectification of the trouble would often transfer the strain to the next weakest link. The history of the development of the hydraulic dredge to its present state of high perfection is a recital of the struggle to overcome a succession of difficulties which arose to plague those who were trying to make a living or to get a job done by such means. Some of the difficulties have been briefly mentioned but there are a few that deserve further discussion.

The spud, for instance, is a very necessary adjunct to a modern cutterhead dredge. At first, dredges were merely moored with lines and moved forward with winches as is still done with the dustpan type. Then some ingenious soul discovered the principle of the walking spud, which is one of the basic elements of the present cutterhead dredge. Until the last twenty years or so, the spuds were of wood, but as the size, weight, and power of the dredges increased, spud casualties became heavy. Then riveted steel spuds were substituted, but when installed in the wells provided for the wooden ones they were difficult to remove when they were bent, as sometimes happened. This led to the gated well at the extreme stern, which is present practice. Next came the cast steel spud, which offered much more rigidity and permitted an increase in length for deep dredging. With the perfection of electric welding, spuds fabricated from steel plate came into vogue, offering sufficient strength combined with lighter weight and lower cost.

The cutter is another part which has been the source of many trials and tribulations since the invention of hydraulic dredges. No matter how perfect the operation of all other components, the cutter or agitator must be able to get the material to the suction or the results are negative. The development of this device has run the gamut of jets, plows, knives, teeth, blades, and various other contraptions. After many years of experimentation, the spiral cutter with inward delivery, with the suction pipe within the periphery, has emerged as the most successful solution. The form is varied, using blades of different sizes and shapes or equipped with teeth, depending on the material to be encountered. Full advantage has been taken of modern methods of fabrication, and of new discoveries in metallurgy to decrease the cost and increase the life of this very vital part.

Some seemingly simple elements such as pipe connections have given dredge operators much concern and have been responsible for many delays. For connections between the suction pipe and the dredge, between the discharge pipe and the floating line, and between sections of the latter, a degree of flexibility combined with strength to resist pressure and failure from bending is required. From the first, rubber sleeves have been employed for this purpose and have served well. Fortunately in the earlier days, pipe sizes were small and pressures low, so that the available materials sufficed after a fashion.

As the pipe sizes increased and the pressures rose, the duty became much more severe so that the procurement of a sleeve that would have a reasonable life became a real problem. However, the automobile-tire industry was faced with the same problem on a much larger scale, and the art of making better rubber compounds and better reinforcing did much for dredging sleeves. Such sleeves, brought to a high degree of perfection, are used in large quantities on modern dredges and pipelines today. The rubber sleeve however is not the final answer for the larger sizes of pipe and high pressures. For such work the steel ball joint and swivel joint have been developed, and while much more costly to manufacture, are in most cases fully justified because of their longer life and freedom from failure.

It is obvious that the pump which is used to pick up and dispose of the excavated material is one of the most important elements of a hydraulic dredge of any type and warrants very careful consideration so that it can meet the varied and severe conditions imposed upon it. The first dredges utilized the only types of pump available—the screw pump or the centrifugal pump designed for handling water. The centrifugal variety soon demonstrated its superiority and is the basis on which the modern dredge pump has been developed.

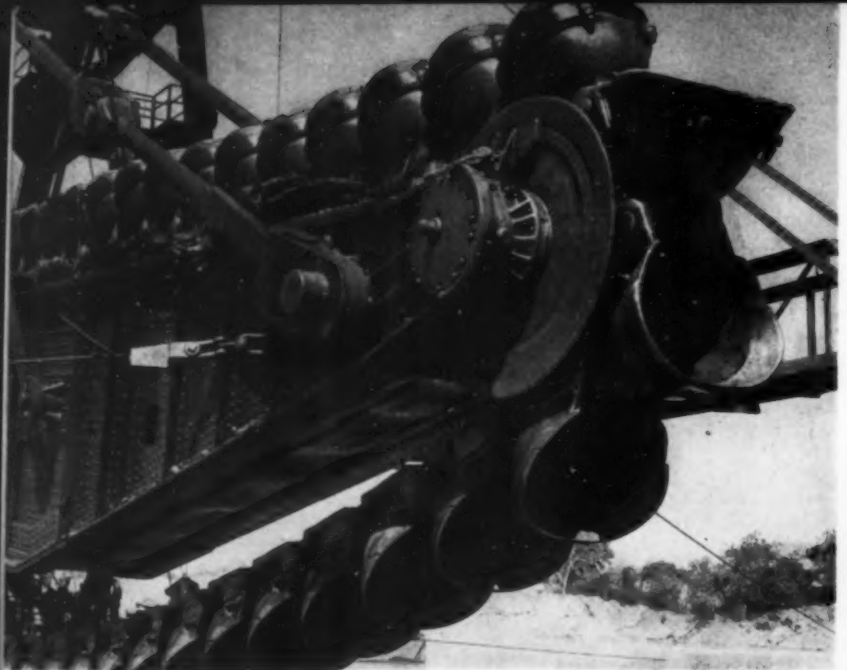
One of the weaknesses of the ordinary centrifugal pump is its tendency to clog when handling entrained material of appreciable size. This characteristic was considerably improved rather early in its development by increasing the size and improving the shape of the water passages to conform to those of the so-called trash pumps developed for drainage work. From that point on however, the gradual perfection of the dredge pump has been an art of its own, developed to meet the unparalleled conditions imposed.

Wear has been one of the major problems with dredge pumps because the inherent nature of the substances handled causes rapid erosion of parts. The first major improvement was the use of removable liners for areas most affected. While this did not reduce the wear, it permitted replacement of parts, rather than of the entire pump. Gradually liners came to be made of materials that were much more resistant to wear, so that their useful life has been increased as much as 400 percent. The use of rubber-faced liners has become prevalent where the nature of the dredged material is such that it will not cause physical damage to them due to impact. The art of vulcanizing rubber directly to steel, so as to avoid exposed fastenings, has made such liners much more successful.

While the large clearances required on dredge pumps make high efficiency impossible, there has been appreciable improvement in this respect due to more scientific and careful design. There are several other features which make the modern dredge pump much superior to those of a few years ago, and it may be safely stated that this element has kept pace with the general improvement in the art of hydraulic dredging.

This article can of course present only a partial picture of what has taken place during nearly a century of development of hydraulic dredges in the United States, but it is hoped that it will give to those who have not been intimately connected with this fascinating industry some conception of the problems encountered and the accomplishments achieved by those who have devoted their time and energy to a work which has proved so beneficial to our waterborne commerce.

(The paper on which this article is based was presented under the title, "The Development of Hydraulic Dredges," by Mr. Giroux at a Waterways Division session presided over by W. O. Hiltabidle, a member of the Division's Executive Committee, at the Centennial Convention in Chicago.)



Bucket

Here's how a big ladder dredge does its work. Above, Yuba Consolidated Gold Fields Dredge No. 20 shows its 18-cu ft teeth. Right, a bucket pin is being changed on a placer dredge.

In February 1952, the Yuba Consolidated Gold Fields Dredge No. 18, rebuilt with two side stackers and a third short stern stacker, started work in the Yuba River near Hammonton, Calif., to replace with one channel the two existing channels built by Y.C.G.F. dredges during the company's placer gold dredging operations 30 years ago. Two other double-stacker dredges were used then in furthering the flood-control program of the Corps of Engineers.

An early California traveler and writer, J. Wesley Jones, reported a dredging machine, the "*Phenix*," in the Yuba River—a "cumbrous" arrangment designed to drag up sand from the bed of the river and obtain gold in large quantities. W. N. Bartholomew made a sketch of this dredge which Mr. Jones used in illustrating his article, "Jones' Pantoscope of California" (*California Historical Society Quarterly*, Vol. VI, No. 3, Sept. 1937). This sketch is reproduced [on the opposite page] through the courtesy of the California Historical Society, San Francisco. For the same society, Earl Ramey wrote an article, "The Beginnings of Marysville," (printed in its quarterly, Vol. XV, No. 1, March 1936) from which the following quotation is made:

> As early as September, 1850 a small river boat, the *Phoenix*, was fitted out as a dredge with which to bring up the placer gold on the river bottoms at points where the water was too high and constant to permit the usual methods of handling it. The first setback for the *Phoenix* was a snag, which sank her with her heavy apparatus. Not until January was the boat taken far enough from Marysville (nine miles) in the Yuba to be tried. The principle apparently was that now in use on the same river. An endless chain of scoops brought the mud up to a rocker-washer . . . .
>
> By the last of April, the *Phoenix* was moved up the Yuba as far as Ousley's Bar . . . .
>
> In June, shareholders were selling stocks at auction . . . . Dredging was a failure for the time.

Successful Dredges Built

The failure of the *Phoenix* discouraged others from attempting to dredge the Yuba until more than half a century had elapsed. Then successful bucket-line dredging was undertaken at approximately the same points on the Yuba River where the early attempts were made. In 1904 Y.C.G.F. dredges Nos. 1 and 2 were built on the Yuba, and in 1905 the Yuba Consolidated Gold Fields company was organized to take over the holdings. Since then, for a period of nearly half a century, this company has operated a total of twenty bucket-line dredges for placer gold mining. The first two dredges had 6-cu ft buckets to dig 60 ft below the water level. As experience was gained, the dredges were equipped with buckets of larger capacity and with digging ladders to reach depths of 80 ft below the water surface. Today, in that area now known as Hammonton, two 18-cu ft dredges dig at depths of 112 and 124 ft below water level and against banks, if necessary, 50 ft in height. Thus a total depth below ground level of nearly 175 ft actually can be dug, a depth equal to the height of a twelve-story building.

Bucket ladder dredging was not new in the United States in the days of '49. In 1805 Oliver Evans had invented and built an "Amphibious Digger" for digging on land or water with a chain of hooks to break the ground and with buckets to elevate the material. History records that Mr. Evans's dredge was used to remove mud from the bottom of the Delaware River at the foot of Chestnut Street in Philadelphia. The first bucket ladder dredge, according to historical records, was invented in 1632, and pictorial records show a dredge used in 1650. P. M. Dakker in his book, *Dredging and Dredging Appliances*, calls attention to this early dredge as the "forerunner of

ladder dredges pay off

C. M. ROMANOWITZ, A.M. ASCE, and HERBERT A. SAWIN

Respectively, Director of Sales and Sales Engineer, Yuba Manufacturing Co., San Francisco, Calif.

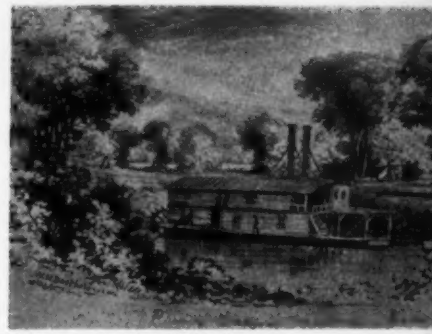


Photo by courtesy of California Historical Society

Above: First dredge, 1850, is shown in sketch by W. N. Bartholomew. Left: Modern dredge of Yuba Consolidated Gold Fields can dig 124 ft below water level against bank 50 ft high. Line carries 135 buckets of 18-cu ft capacity. Dredge displaces about 4,000 tons and has installed electrical load totaling 2,175 hp. Dredge of this size, digging deep, can handle 10 to 12 thousand cu yd daily with three shifts or, digging at depth of 80 to 100 ft, as much as 15,000 cu yd.

Dredging on Yuba River, California, 1850–1950

the bucket dredger." The earliest dredges were used for excavating mud from channels in the low countries of Europe.

The bucket ladder dredge is considered to be the first equipment successfully used for deepening harbors, but for such use and other excavating it was never developed to the same efficiency as the bucket ladder dredges used in placer mining. For harbor work it was developed to a certain point, but was more or less displaced by the hydraulic suction dredge. Whenever materials were to be conveyed a distance from the dredge, the best method of transporting them, until recent years, was by water through a pipeline. The bucket ladder dredge excelled when the excavated material was to be dumped directly into barges alongside of the dredge, or deposited in its immediate vicinity by belt conveyors. For this reason, when harbor work was necessary and a hydraulic dredge was available, it was often used in places where a bucket ladder dredge could have worked more efficiently.

Advantages of Bucket Ladder Dredge

In placer mining, the bucket ladder dredge was developed to its present high efficiency because, after many of the original rich placer gold deposits were worked out, it was necessary to work to greater depths and handle gravel of lower value to keep the industry alive. To meet these two extreme conditions, it was necessary to lower operating costs, and increased dredging efficiency was the only way to do so.

The bucket ladder dredge has three chief advantages over the hydraulic dredge:

1. The ladder dredge has equipment and power to excavate harder and more tightly bound materials. The weight of the digging ladder and buckets can be used to hold the bucket line in position while digging.
2. The gravel, rock, or other materials thus dredged are all "payload." The energy applied delivers to the surface concentrated material with little water, not just a partial load as is delivered in a water-conveying system.
3. Since the belt-conveyor system has been developed to its present efficiency on various large construction projects, it is practicable to make use of belt conveyors to transport materials to points far beyond the dredge. Previously such material was transported by using water through pipelines as the carrying medium.

At Panama, the canal was dug partly with several bucket ladder dredges, one, the *Corozal* using 54-cu ft buckets. Since dredging of this type was done only to deepen waterways, the greatest depth was only that needed for ships, a maximum of about 40 ft below water level. It was not until the placer gold operators adapted bucket ladder dredges of the California type to their use that a depth of 60 ft was reached. This was accomplished with Y.C.G.F. dredges Nos. 1 and 2, built by the Bucyrus Company in the Yuba River in 1904 as previously noted.

Experience with deep-digging dredges was gained rapidly by the gold-dredge operators, and their experience in California was made use of by dredge operators in the tin fields of Malaya and elsewhere. One California firm, the Yuba Manufacturing Company and its predecessors, has built bucket ladder dredges for use throughout the world in most of the known placer mining areas. Experience gained in placer dredging has been adapted to other engineering fields. Yuba dredges have been designed and proposed for excavating rock in the Panama Canal when and if a sea-level canal is built to replace the present system. Studies made recently, and reported comprehensively in the ASCE PROCEEDINGS for April 1948, include the use of Yuba bucket ladder dredges with 54-cu ft

Bucket ladder dredge equipped with double stackers constructed flood control channel 500 ft wide on Yuba River about thirty years ago. Bucket size was 18 cu ft.

buckets capable of digging 145 ft below water level. The buckets for these dredges would be designed especially to excavate blasted rock. The excavation of boulders and rock is not new to placer dredge operators; many such dredges have been used where it was necessary to pick up rock and boulders, sometimes larger than the buckets themselves.

Amazing Channel Dredging Job

One of the excavating jobs that attracted attention to the work which could be accomplished with a deep-digging bucket ladder dredge was undertaken by Yuba Consolidated Gold Fields near Hammonton about 30 years ago. Two of its 18-cu ft dredges were equipped with double stackers for levee construction and, while they carried on the gold dredging program, digging approximately 80 ft below water level, they stacked the rock tailings in three parallel levees. These levees formed two new water courses, each about 500 ft wide and approximately five miles long. A third stacker was used on each dredge to restore the river bottom to its natural elevation. This work was undertaken under an agreement with the U. S. Corps of Engineers, and these two channels are credited with so controlling the water level in the Yuba River during flood periods for over a quarter of a century, that when the water was still rising in the channels 12 miles upstream from Marysville, it had started to recede from its high mark on the Marysville levees.

The new channel, mentioned earlier, will be constructed on the north side of the river, against high ground. Two levees, approximately 600 ft apart, will be built to replace the existing two channels built 30 years ago, and the bottom of the river will be maintained at its normal elevation by filling behind the dredge with a short stacker supplementing the work of the two long side stackers. The new work is designed to improve conditions on the river. The channel, in so far as dredging costs are concerned, will be built at no expense to the county or Federal Government, despite the fact that the gravel dug will not have a gold content up to the average of past operations for the reason that most of the ground has been dug at least once before.

Other construction work accomplished by a dredge built originally for dredging gold-bearing gravel, was that carried out by No. 137 built by the Yuba Manufacturing Company, at the site of Canyon Ferry Dam on the Missouri River in Montana. Built originally for the Perry & Schroeder Mining Company for mining gold, with sapphires and garnets as by-products, this dredge was in a favorable location when work was started by the contractors on the new dam for the Bureau of Reclamation. In the summer of 1949 the dredge started to dig out the construction area preparatory to unwatering the dam site. Much of the excavated gravel was used to build two cofferdams, the dredge stacking gravel behind sheetpiling to divert the flow of water. This was a new use for a bucket ladder dredge. Later the dredge was used to strip the dam site while dumping gravel to a stock pile for disposal by truck, or for use later as aggregate. This dredge has 6-cu ft buckets capable of digging 48 ft below water level, and the stacker elevates the gravel to a point about 48 ft above water. Operating three shifts, a dredge of this size can move about 6,000 cu yd of gravel daily.

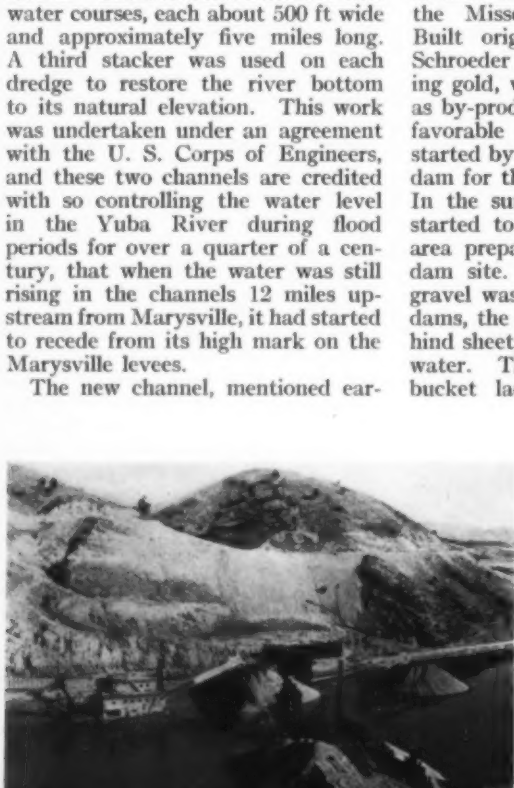
Good Dredging Practice

Good California practice for bucket ladder dredging is to dig with the maximum depth reached while the ladder is at 45 deg to the water level. Digging can be accomplished with the ladder more nearly vertical, if desired, but it is not recommended as a general practice. Digging is started at the top of the face and, as the bucket line moves upward with the excavated material, the dredge swings to the right or left about the spud, which is at the stern and imbedded in the pond bottom.

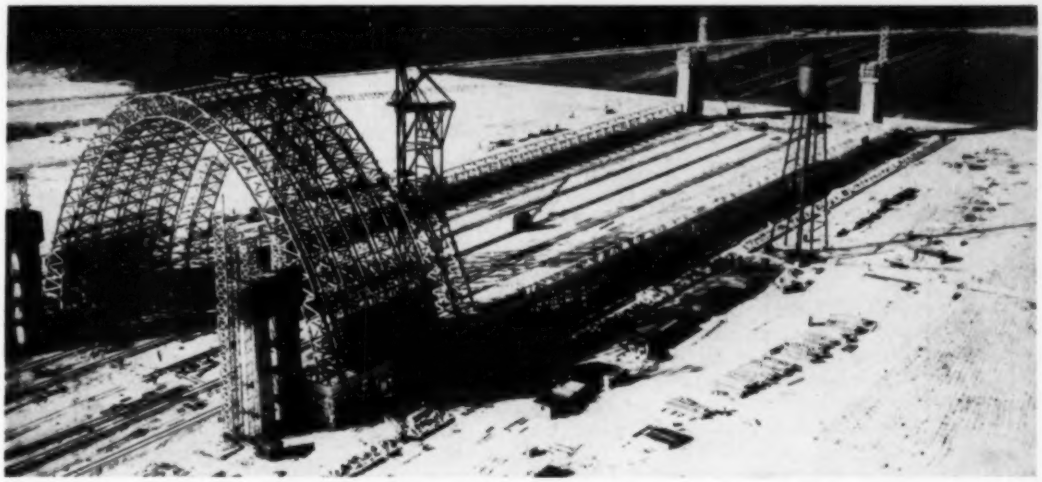
Dredging can be accomplished by use of a head line, but this practice is not as satisfactory as when a spud can be used, since the spud takes the thrust of digging, distributing the load to fore and aft trusses. The side swinging is accomplished by port and starboard bow lines, usually carried from the underwater point of the digging ladder to shore blocks, then back to the bow of the dredge and to the swing winch, usually mounted inside the deckhouse. As one drum of the winch takes up the bow line on one side, the other drum pays out a slack line to the other side. When the swing is completed, the operation is reversed.

Modern bucket ladder dredges are built with the digging ladder motor mounted behind the upper tumbler, the sprocket-like device which moves the line of buckets. The bucket line, in placer dredging, usually moves at speeds of from 20 to 30 or more buckets per minute. The advantages in having the drive mounted behind the upper tumbler are that two drive motors can be used, one on each side of the drive, and that the motors can be connected by V-belts to the reduction gears. This is the type of drive used on Y. C. G. F. dredges on the Yuba River. The total amount of gravel dug near Hammonton far exceeds the volume of material handled in the digging of the Panama Canal.

Our 1850 reporter, Mr. Jones, would be quite surprised if he could visit his Yuba River dredging site today. The owners of the "*Phenix*" had the right idea, but lacked the mechanical means of accomplishing the dredging they had in mind.



At Canyon Ferry Dam site on Missouri River, Montana, 6-cu ft bucket ladder dredge owned by Perry & Schroeder Mining Co., made itself generally useful. It is seen here constructing cofferdam in Missouri River.



Timber trusses used by U.S. Navy for blimp hangars are striking example of metal-connector construction.

Wood as an engineering material

L. J. MARKWARDT, M. ASCE

Assistant Director, Forest Products Laboratory

Maintained at Madison, Wis., by U.S. Forest Service in cooperation with University of Wisconsin

As a result of the unprecedented engineering and related scientific progress during the past century, the engineer today has available a vast choice of materials that permit a seemingly infinite variety of design and appearance. Yet this diversity of materials, together with the advances and developments in technical information concerning them, has imposed on the engineer the serious problem and challenge of keeping abreast of developments and of current literature. It has brought about the necessity of specializations—of knowing more and more about less and less—and developing means of integrating these specializations. In no field is this more true than with wood, which on the one hand has shared with other materials the significant progress that has widened their horizons of use, and on the other, because of its orthotropic structure, has presented more complications from the standpoint of properties and design details.

Wood is among the oldest structural materials and has served men from time immemorial. It is not difficult to imagine that perhaps a fallen tree served as the first bridge across a stream. Later, fashioned by the skill of early craftsmen, wood structural elements found their way into monumental structures, many of which are still in existence. It is a far cry from the empiricism of yesteryear to the efficient timber design of today.

The Place of Wood

In this industrial and mechanical age, with its guided missiles and push-button techniques, the question may well be asked, "What is the place of wood, one of our earliest and still one of our most abundant raw materials? Can wood and wood products compete with other materials in a mechanical age?"

On every hand, and in thousands of uses, there is abundant evidence of the utility of wood itself, as well as of wood-base materials processed through mechanical and chemical conversion—railway ties, transmission-line poles, piles, mine props, furniture, buildings, paper, rayon, photographic film, and smokeless powder, to mention but a few.

More specifically, there are nearly 2,000 miles of wood trestles and bridges on the first-class railroad lines of the United States. Thousands of large modern structures employing relatively new techniques and developments in the form of wood trusses and glued laminated arches have been constructed. Of the more than one million homes a year built in the unprecedented postwar housing program, more than 75 percent are of wood-frame construction. The consumption of wood-fiber products has been materially increasing. The commodities today being made in unprecedented volume are largely packaged for shipment in wood or fiber containers, and the chemical products of wood are finding new and unpredictable uses and applications almost daily.

In addition to normal requirements, a larger quantity and greater variety of wood products are required for modern war than ever before. In naval use, for example, wood and steel rank as the two principal structural materials for building and maintaining the modern fleet. Approximately 9 million tons of steel were required by the Navy in a single war

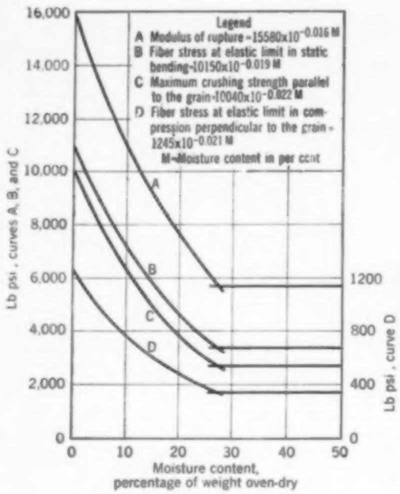


FIG. 1. Strength of small specimens of clear Sitka spruce increases with loss of moisture.

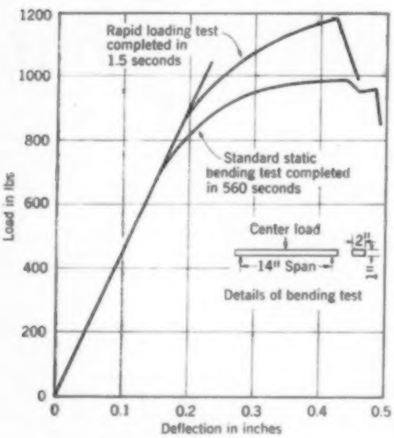


FIG. 2. Sitka spruce specimens withstand higher ultimate stress under rapidly applied load than under slowly applied load.

year. Wood requirements for a similar period were 3 million tons, and wood was rated first in volume and second in tonnage of raw materials needed for all types of naval military construction, afloat and ashore. More then 2,000 vessels and 43,000 small boats were made of wood during World War II.

Forest products industries collectively constitute big business, largely carried on by little businesses. There are some 25,000 to 50,000 small sawmills scattered over the country which, together with a limited number of larger mills, provide our lumber production. The wood products industries employ about 2 million people, produce material valued at more than 10 billion dollars annually, and in 1939 ranked fourth in number of wage earners and sixth in value of product.

In the United States alone the annual lumber production in recent years has been on the order of 35 to 40 billion board feet. Of this production, about 60 percent is used for buildings and other construction in a normal year. On a per capita basis, the lumber consumption has, with some deviations, continued at the very high level of over 200 board feet per capita during the past century.

Parade of Technical Progress

Let us review some highlights in the use of wood during the past century, most of which have taken place within a single life span. The turn of the twentieth century found the United States with a splendid heritage of forest resources. Basic information about the strength properties of American species was, however, very scanty, inadequate, and unreliable for engineering purposes as regards all but a very few species of old growth. With the establishment of research facilities, the evaluation of physical and mechanical properties of wood was promptly recognized as one of the most important needs. Since test data are intimately related to test methods, it was first necessary to develop systematic standard test procedures. The procedures followed conform to ASTM Standard D143-52, "Standard Methods of Testing Small Clear Specimens of Timber."

During the past fifty years, extensive basic data have been obtained on the strength and related properties of some 200 species of wood. These data are now being extended to cover second-growth timber, which often is found to have somewhat different characteristics from old-growth timber. Considering the many species of trees and their differences in growth characteristics, there will be a continuing need for further evaluation.

It has long been known that many factors affect the strength of wood, but continued research has greatly widened our knowledge concerning them. Among these factors are moisture content, rate of loading, duration of stress, temperature, direction of grain, position of growth rings, and the influence of such growth and inherent variables as knots, cross grain, shakes, and checks. Through extensive studies on the effect of moisture content, for example, it has been shown that most strength properties increase with loss of moisture below the fiber-saturation point, and that the relationship of strength to moisture can be expressed as an exponential curve. (See Fig. 1.) The mechanics of moisture-strength adjustment has thus been established for wood in which the moisture is

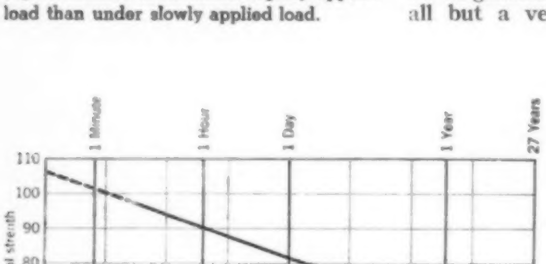


FIG. 3. Test data indicate that working stress of Douglas fir for loads of short duration can be materially increased over normal working stress for long-time loads.

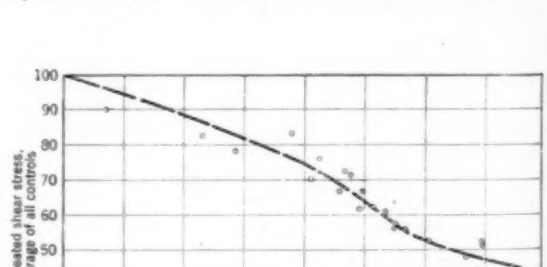


FIG. 4. Tests of laminated glued shear specimens of Douglas fir show that wood ranks high in resistance to fatigue.

uniformly distributed so that there is no moisture gradient.

Likewise, related studies have shown the effect of knots with respect to size and position in structural members, and the effect of cross grain, shakes, and checks. These data serve as a basis for establishing limitations on the natural characteristics that affect strength, for the purpose of assigning definite working stresses to structural timbers according to grade.

Structural Grading of Timber

Individual pieces of lumber, as they come from the saw, represent a wide range in quality and appearance with respect to freedom from knots, blemishes, defects, and other characteristics. Such random pieces, consequently, also represent a wide range in strength, utility, serviceability, and value. An obvious requirement for the orderly marketing of lumber, therefore, is the establishment of grades, the function of which is to provide utility classes that make it possible to segregate individual pieces generally similar in desired characteristics.

Many grades for lumber are established on the basis of the appearance and physical characteristics of the piece, with certain uses in mind but without particular regard for strength. Other grades, called structural, are based on the classification of features relating to strength and strength uses. Marked improvement and unification in lumber grading resulted from the establishment of American Lumber Standards, and from the adoption by manufacturers of structural grades that permit the assignment of definite working stresses.

Through the analysis and integration of available data, a comprehensive set of simple basic principles for grading structural timber has been established, and has been adopted by the American Society for Testing Materials under the title, "Tentative Methods for Establishing Structural Grades of Timber," ASTM Designation D245-49T. The basic principles are applicable to all species of wood and permit the establishment of grades for different classes of lumber having any desired percentage of the strength of the clear wood. The important lumber-producing associations now provide lumber that conforms to the basic principles of structural grading and to which definite allowable working stresses can be assigned. This development is one of the most important from the standpoint of permitting efficient and economical timber engineering design.

Working Stresses Established

Safe working stresses are an essential corollary of structural grading. While tables of working stresses abound in engineering literature, many of the early recommendations were based on fragmentary and inadequate strength data, and on very incomplete information about factors affecting strength. As a result, the recommendations often varied widely among themselves, were usually overconservative, and generally were not associated with particular structural grade requirements.

As technical research data became available on basic factors affecting strength and on properties of different species, a complete reanalysis of working stresses for structural timber was made. The principal factors entering into the establishment of the recommended working stresses for each species include the inherent strength of the wood, the reduction in strength from natural characteristics permitted in the grade, the effect of long-time loading, the variability of individual species, the possibility of some slight overloading, the characteristics of the species, the size of member and related influence of seasoning, and the factor of safety.

The effect of these factors is to require a lower strength value for practical use conditions than the average value obtained from tests on small clear specimens. Their combined effect may be embodied in a single factor, sometimes erroneously called a "factor of safety," which can be applied to averages from tests on small clear specimens to obtain safe working stresses. It is evident that the larger part of this factor is required to correlate laboratory test results with actual conditions of use, and that only a small part can be considered a true factor of safety.

The revised working stresses for the commonly available commercial species of lumber provide a means of economical and efficient design, particularly when used with structurally graded lumber. The working stresses have been widely accepted in general engineering design, and significantly are being incorporated in current revisions of engineering handbooks. They are the basis for the design recommendations presented in the National Design Specifications published by the National Lumber Manufacturers Association.

Duration of Stress

Wood is among the materials that are affected by rate of loading or duration of stress (Fig. 2). Studies have been under way to obtain more definite information on this factor as it affects design procedure. These studies have included rapid-loading tests, in which the maximum load may be reached in a few seconds or less, for use in aircraft design; and so-called dead-load tests, in which constant loads are applied for long periods of time or until failure occurs.

Studies on the effect of rapid loading have confirmed some less extensive earlier results, which show for Sitka spruce, at 12 percent moisture content, a 17 percent increase in modulus of rupture in bending for 3-sec loading over that for the 5-min loading in the standard static bending test.

Data have also been developed that provide a basis for modification of working stresses for loads of short duration, such as wind stresses and other conditions that involve engineering judgment. For example, a curve has been devised to express the relation between load in bending and duration of stress for small clear specimens of Douglas fir at a constant moisture content of 12 percent. Load is expressed as a percentage of normal strength, as in Fig. 3, and the duration appears on a logarithmic scale. The solid part of the curve indicates the limits of the test data in this study. Prolongation of the line in the direction of higher load is verified by other tests, while extrapolation in the direction of the lower load is yet unproven. These results are applicable to conditions of uniform moisture content.

Wood Resists Fatigue Well

Another phase of research relates to the development of engineering data on fatigue. Fatigue tests of wood and glued wood constructions have indicated that failures due to repeated or reversed loads develop in much the same manner as they do for metals, except that, in fatigue of wood, the appearance of the failures produced by repeated loads is similar to that of failures produced by a single loading.

The "S-N" (stress versus number of cycles to failure) curves obtained from tests of wood or wood-base materials are similar to those obtained for nonferrous metals; that is, the curves are concave downwards for high levels of stress and concave upwards for the lower levels of stress, and the two curved sections are usually connected by an approximately straight line.

Comparisons of the results of tests on fatigue of wood with those on certain other materials suggest that,

Design values for timber connectors are based on results of many laboratory tests. Since 1930, connectors have been used directly on a billion board feet of lumber.

Timber roof trusses in building at Forest Products Laboratory, Madison, Wis., have metal connectors and bolts at joints.

when other things such as conditions of loading are equal, wood ranks relatively high in fatigue resistance. For example, fatigue tests of wood in tension parallel to the grain indicate that the level of stress at which the specimen can be expected to sustain many million cycles of stress without failing is a greater percentage of the static strength than for some metals in tension. Data from these and similar studies, such as that shown in Fig. 4, are being published as they become available, and give reassurance regarding the ability of wood to withstand fatigue, and on the performance of glued construction as well.

Joints and Fastenings Important

Because of the wide difference in the properties of wood along and across the grain, joints and fastenings are the Achilles' heel of timber construction wherever they are employed. The older common forms of fasteners include nails, screws, bolts, lag screws, and drift pins. All of these forms have advantages and limitations.

One of the newer types of fastenings that have greatly widened the horizon of wood construction is the so-called metal connector. When this connector was introduced into the United States in 1930, its possibilities were quickly recognized. Strength tests established the most promising forms, and furnished basic design data for use under optimum conditions. Simultaneously, commercial development of certain improved types occurred.

The use by the construction industry of timber connectors in trusses and other heavy timber construction, on the basis of the technical design data developed, permitted the erection of large structures hitherto beyond the range of timber design. In the decade after their introduction, more than 100,000 structures were built in which modern connectors were used, employing about 5 billion feet of lumber valued at $165,000,000. The amount of lumber in these structures used directly with the connectors approximated 1 billion feet.

Connectors are devices used in conjunction with bolts to increase the efficiency of joints in wood members. The split-ring type fits into precut grooves; the alligator type is pressed into the wood between the members to be jointed; other types fit into bored recesses. Whatever the type, they all serve to reinforce the joint by providing effective shear resistance between the members. Research has included evaluation of the strength of several of the types in a range of sizes, applied in various ways, when used with different species of wood.

Glued Laminated Construction

Developments in adhesives and in gluing techniques—a result of cooperation among chemical industries, wood industries, and research laboratories—have made available adhesives to fit nearly any condition of service and have led to the establishment and expansion of the glued laminated construction industry. The products of this industry—structural members glued up from smaller pieces of wood, either straight or in curved form, with the grain of all laminations in the direction of the length of the member—have found wide acceptance because of their versatility and architectural possibilities.

A considerable amount of research has led to the development of a background of data for the establishment of design procedures. Tests on arches, beams, and columns have covered such factors as the effect of knots, stress concentrations around butt joints, effectiveness of end joints of various types, effect of bending laminations to a curved form prior to gluing, and the like.

In addition to laboratory tests, experimental installations to determine the practicability of large laminated timbers have been made on a number of railroads. The practicality of this type of construction for a variety of applications has been demonstrated over the past twenty years or so in this country and for more than twice that long in Europe by the good service of existing structures. [In another article in this issue, Alan D. Freas, A.M. ASCE, presents many advantages and applications of glued laminated timber construction.]

The character, orientation, and arrangement of the fibers make wood an anisotropic material. For all practical purposes, however, it may be treated as orthotropic, with three principal axes of symmetry, the longitudinal, the radial, and the tangential. The assumption of three structural axes results in a variety and complexity of properties. These are: three

Wood centering is used in construction of long-span concrete arches.

Young's moduli, varying 150 to 1; three shear moduli, varying 20 to 1; six Poisson's ratios, varying 40 to 1; and nine strength properties, varying with grain direction (three in tension, three in compression, and three in shear). These widely different properties of wood along and across the grain involve a complicated mathematical treatment in special design problems. Through basic research, general formulas have been established for the solution of critical design problems for wood.

Plywood Has Many Applications

Plywood is another wood product that is dependent on adhesives, and provides a dimensionally stable product of unique properties in large sheet form. In plywood, the orthotropic structure of wood is further diversified by a reorientation of the material. It consists of a combination of three or more sheets of veneer, with the grain of alternate plies usually at right angles.

Because plywood can be made with any desired number of plies, from veneer of any desired thickness and from any desired species or combination of species, it has a versatility that affords almost unlimited choice in design for special purposes. Further diversification can be obtained by orienting the grain of adjacent plies not only at right angles but at various other angles. In this way a material can be constructed to meet special design needs for aircraft and other uses. Dimensional stability results from the cross-banded construction, and freedom from warping and cupping is obtained by using balanced construction, which invariably consists of an odd number of plies.

In reorienting the direction of the grain of the veneer to make plywood, the strength of the wood in one direction is improved at the expense of that in the other direction. The greater the number of plies for a given thickness, the more nearly equal are the strength properties in the two directions of the panel, and the greater is the resistance to splitting.

"Stressed-Skin" Construction

Another significant research development with various possible fields of application is "stressed-skin" construction, which has served as the basis for panel design in prefabricated house construction. The principle of the stressed skin is founded on the engineering concept that all material in a structure should contribute directly to its strength, as compared with conventional frame construction, in which a frame carries the interior and exterior wall covering largely as "parasite" material.

Stressed-skin construction is secured by gluing sheets of a rigid material, such as plywood, to either or both sides of an inner structural framework to form what is virtually a box girder. The stressed-skin principle of prefabricated construction thus gives opportunity to design more closely and with greater economy of material.

As an example of the strength and stiffness that can be obtained with smaller than conventional sizes, a 14-ft, stressed-skin floor panel about 6 in. thick has a maximum strength as a beam of about 300 psf, with a deflection less then $^{1}/_{300}$ of the span at design load. A 3-in.-thick wall panel has a transverse strength equivalent to 200 psf.

Sandwich and Composite Construction

There has been a growing interest in the possibilities, for many applications, of lightweight composite or sandwich construction. While the concept of sandwich construction is new, it is the combination of the relatively recent significant advances in adhesives and fabricating techniques, the development and availability of a variety of facing and core materials, and particularly the stim ulated need for more efficient lightweight structures in aircraft, that has brought about the sandwich era.

Special mention is made of sandwich construction because of the extensive use of wood and wood-base materials for facings and cores, and because the design criteria for plywood provided a logical and effective springboard for the development of design criteria for sandwich construction.

Present and potential uses for sandwich construction include radomes, airplane fuselages and wings, airplane flooring, doors, bulkheads, ailerons, and flaps; walls, ceilings, and partitions in railway cars; hatches, partitions, and bulkheads in boats; and doors, frames, wall panels, and floor panels in houses.

Through the cooperation of the Navy Bureau of Aeronautics, the Air Force Air Materiel Command,

Southern Railroad trestle bridge incorporates glued laminated stringers, caps, and posts. Timber in this case was creosoted after laminating.

and the Civil Aeronautics Administration, extensive design data for sandwich construction particularly applicable to aircraft design have been developed at the Forest Products Laboratory, but the methods are generally applicable to all sandwich design. The transportation industries have much to gain through lighter-weight constructions, and are exploring the possibilities that sandwich design offers. Thus, the already significant developments in sandwich construction in recent years presage ever-increasing applications to a wide variety of uses. Each type of use has its own requirements, its own range of possibilities, and its own problems to be solved.

A composite construction, in which a creosoted timber base is overlaid with a lightly reinforced concrete mat intimately bonded to it in shear, has been extensively employed in bridge decks, piers, and other heavy-duty flooring systems. Special shear keys or other types of shear developers are employed to secure adequate bond between the two materials. A significant advantage of composite construction is its simplicity, in that joist-and-stringer systems are not required and the timber base serves in lieu of form material for supporting the concrete when poured. A considerable number of projects employing a composite design of wood and concrete are currently under construction.

Destructive Agencies Controlled

There is of course no such thing as absolute permanence for any engineering material under all conditions of service and use. Wood is no exception and requires the control of a group of destructive agencies largely peculiar to itself. The principal causes of the deterioration of wood, in their general order of importance, are: decay, fire, insects and marine borers, mechanical wear and breakage, weathering, and chemical decomposition. Damage or total destruction may result from any one of these causes alone, but it is more common where two or more of them are at work at the same time.

As a result of research and experience over a great many years, control and remedial measures are available to guard wood against most, if not all, of the destructive agencies to any desired extent. Economic considerations enter the picture also, in establishing a balance between the cost of protective measures when this cost is substantial, as against the cost of replacement. In the problem of control, it is at once essential to know the nature of each of the destructive agencies and the conditions under which it develops.

Decay in wood is produced by organisms know as fungi, which live on the wood substance. Wood-destroying fungi require favorable conditions for their development with respect to moisture, temperature, and air; hence, if any one of these requirements is eliminated, the growth of fungi will be inhibited. Thus wood that is below a certain critical moisture content presents no decay hazard. Likewise, by maintaining wood at extremely high or low temperatures the development of fungi is prevented, just as it is where wood is immersed in water.

Under conditions favorable to decay, two effective methods of prevention may be employed: (1) select species of high natural resistance to decay, or (2) use a preservative treatment. A considerable variety of wood preservatives are available to meet different requirements.

Much study has been given to means for protecting wood from fire and for retarding or preventing the effects of exposure to fire. Fire-retardant coatings have been developed that are effective on interior finishing or structural wood products. Impregnation treatments with suitable chemicals may also be employed to impart fire resistance to wood. It is generally recognized that large structural members of wood do not readily support combustion, and because of their low thermal conductivity maintain loads over considerable periods of fire exposure.

Wood Lasts Indefinitely

While wood, like other materials, is subject to attack by various destructive agents, methods are in general available to prolong its life when destructive agents are to be encountered. So far as is known, the lignin and cellulose which constitute the wood substance are not subject to chemical changes with time when kept dry, although the color of wood may be slightly changed by long-continued exposure to air. Consequently wood can be expected to last indefinitely when not subjected to deteriorating agencies.

Literally hundreds of well-designed bridges made entirely or partly of wood have served satisfactorily and with but little attention for long periods. Many that are more than a century old are still in service. Others, while still in satisfactory condition, have been altered or replaced to meet demands for greater width of roadway and higher load capacity than was called for when they were built.

In Europe, many wood structural units that are centuries old are still in existence. Perhaps the most notable are the trusses in the Basilica of St. Paul at Rome, part of which was constructed in 816, during the pontificate of Leo III. Certain such roof trusses are known to have given service for more than a thousand years.

Future Research Needed

Significant as have been the achievements relating to the more efficient engineering uses of wood, it should not be overlooked that there are still many challenging possibilities ahead. One important possibility is that of developing a system of preferred stresses so as to greatly reduce and simplify the number of design stresses to be used. Such a development would permit design at some selected stress level, with the assurance that suitable material to carry out the design would be available from a choice of species, or at some future time. Another important contribution to timber design would be the simplification of design procedures, which admittedly are now more complicated than for most other materials.

Much more research is also needed on joints and fastenings, to include the integration and unification of data for the various types of fastening mediums. More detailed and basic information is needed for the design of structures subjected to sudden or shock loading, such as that due to earthquakes, in order to insure safety and permit more economical design. These are but a few of the many problems awaiting extensive research to further widen the horizons of timber design and use, and to aid timber design in keeping pace with developments in other materials and with the requirements of the modern age.

Wood is unique in being a renewable resource. As long as the sun shines and the rains fall, there need be no shortage of wood in the world if we manage the forests well and learn to use the tools of industry, products of our industrial civilization, for the more nearly complete employment of wood in meeting human needs. The forest resource is unique in that its proper harvesting is the best possible means of insuring a permanent timber supply.

(This article is based on the paper presented by Mr. Markwardt in the symposium on wood, sponsored jointly by the ASCE Structural Division, AREA, ASTM, and ASME Wood Industries Division, at the session presided over by Mr. Markwardt, held during the Centennial Convention in Chicago.)

A survey of timber highway bridges in the United States

RAYMOND ARCHIBALD, M. ASCE, Chief, Western Headquarters, Bureau of Public Roads, San Francisco, Calif.

Historic records of the use of timber in highway bridges show that the important part timber played in the development of highways in America began, not a hundred years ago, but more than three hundred years ago. It may be that the earliest bridges should not be classed as engineering feats, but they did require ingenious methods for their day.

The first wooden highway bridges connected with American history were probably three bridges constructed in the Bermuda Islands in 1620, or 332 years ago. The first bridge built in North America was a horse bridge over Neponset River, near Neponset, Mass., in 1634. It was destroyed in 1655 and replaced with a cart bridge. In 1635, a footbridge was erected at Ipswich, Mass., which was later widened.

Pile Trestles First Used

Perhaps the first highway bridge of importance was constructed 191 years ago, in 1761, over the York River at York, Me., by Samuel Sewell, a civil engineer. This bridge is especially significant because it is the first one on record that was built from plans predicated on a survey of the site, and was the first pile trestle structure. It was 270 ft long, 25 ft wide, and was supported on 4-pile bents spaced approximately 19 ft on centers. The bents, assembled with caps and bracing, were driven as a unit, the length of the piles having been previously determined by probing the stream bed with an iron-shod pole.

The driving of the pile bents was quite an achievement in itself. After the bents were hoisted in place, the butt ends of the heavy logs, the tips of which were attached to the previously driven bent, were raised and let fall with considerable force on the cap. The York River bridge contained a draw span to allow for the passage of sloops.

In 1785, another pile trestle bridge was constructed over the Charles River between what were then Boston and Charleston, Mass., by methods similar to those used on the York River bridge. Its total length was 1,503 ft including the draw span, and it had a 42-ft roadway and a 6-ft sidewalk. The camber for the entire length was 2 ft. Forty lamps were installed for illumination. Here, built 167 years ago, was a bridge with a draw span, wide roadways, pedestrian walks, lighting, and camber.

The proprietors of this bridge were required to pay annually \$666.66 "in consideration of the income loss from ferriage," to a ferry located nearby. Apparently toll ferries and bridges had their difficulties then, too.

Trusses and Arches Introduced

The development of the timber arch and truss spans widened the field, and marked the beginning of a period of bridge construction unprecedented in history. Records of a bridge over the Shetucket River at Norwich, Conn., built 188 years ago, in 1764, indicate that a truss might have been used for the first time. The account reads:

> It is 124 ft in length and 28 ft above the water. Nothing is placed between the abutments, but the bridge is supported by Geometry work above, and calculated to bear a weight of 500 tons. The work is by Mr. John Bliss, one of the most curious mechanics of the age.

Built in 1792, the Essex-Merrimac Bridge near Newburyport, Mass., had two 160-ft arched-truss spans. The Piscataqua Bridge near Portsmouth, N. H., contained a "stupendous arc," the chord of which was 244 ft, 6 in. long. The ribs were made up of curved timbers hewn from crooked logs and framed to produce firm abutting joints, which were staggered to secure rigidity and strength.

Laminated timber members were used 148 years ago, in 1804, in the Trenton Bridge over the Delaware River between New Jersey and Pennsylvania. The ribs were made of 4 x 12-in. planks on edges built up to form ribs 3 ft wide.

Another engineering feat was accomplished in 1814 with the construction of the McCall's Ferry Bridge over the Susquehanna River at McCall, Pa. This timber-arch span 360 ft long was to be erected on scows to be floated into position. However, an ice jam prevented the use of this method, so the ribs were cut in half and skidded into place, resting on falsework supported by the ice.

Ithiel Town, in 1819, developed a timber truss which was patented in 1820, consisting of a top-and-bottom parallel chord with inclined members forming a latticework, and with vertical posts at the piers. The truss members were usually built of 2 x 10-in. and 4 x 14-in. planks.

William Howe obtained a patent in 1840 on a parallel-chord truss which permitted a complete stress analysis by a mathematical practice then in use. Thus, it appears that even 112 years ago, our forefathers were applying engineering to highway bridges of timber. Now what about these intervening 112 years?

Pressure Treatment Introduced

Probably the most significant development affecting highway bridges has been the introduction of the pressure preservative treatment of timber. With the advent of steel and concrete, the useful life of the timber bridge had to be extended if it was to compete with these new materials. This useful life had been greatly lengthened in the covered bridge, in which the truss members were protected from the elements, but this was not entirely satisfactory.

Pressure treatment of piles was an important improvement because untreated piles deteriorate swiftly at the ground line and render the remainder of the structure useless. Stringers and caps were also given this treatment. The laminated timber deck

(*Continued on page 259*)

Laminated arches span 46-ft-wide building at U. S. Forest Products Laboratory, maintained at Madison, Wis., in cooperation with University of Wisconsin. Arches and curved beams lend themselves to variety of architectural treatments not possible with lumber of large cross section.

Laminated

Developments in the use of wood over the centuries have been many. It is a far cry from the use of trees and logs for bridging streams to the modern methods of using structural-grade timber and metal fasteners. The purpose of this article is to discuss one of the most recent developments in this field—one that promises not only to give us better and more versatile structures, but to have a considerable influence on our timber economy by permitting the more efficient use of smaller sizes and lower grades—glued laminated lumber.

Glued laminated lumber is an assembly made by bonding layers of lumber or veneer so that the grain direction of all laminations is essentially parallel. Thus, it differs from plywood, in which the layers of veneer, or of veneer and lumber, are cross-banded, usually with the grain directions of adjacent layers at right angles.

The laminating industry is young and virile, worthy of the attention of engineers and architects seeking a solution to their structural problems. From a small beginning, shortly after the first World War, the manufacture and use of laminated wood grew to the point where, in World War II, it was an important factor in solving problems of shortages in vital materials. Not only were arches, beams, and truss parts laminated for use in buildings, but aircraft spars, ship keels, frames, and other members were furnished in large numbers. New and expanded applications have been developed since World War II.

Glued laminated wood has a number of advantages over solid lumber or timbers. Perhaps those of greatest significance are:

Essentially unlimited size possibilities. This is of particular importance in view of the diminishing stands of timber that furnish the large sizes required for such structural members as girders and bridge stringers.

Improved utilization of our timber resources. Standard commercial sizes of lumber, which would otherwise have little or no structural application, can be used to produce large structural members. Further, lower grades of lumber than are used in the outer, higher-stressed laminations can be utilized in the inner, lower-stressed laminations of beams and arches without seriously affecting the strength of the member.

Freedom from severe checking. Since the laminations are generally thin enough to be readily seasoned without severe seasoning degrade and since gluing requirements necessitate relatively low moisture contents, the checks and other defects commonly associated with large one-piece members can be avoided. Furthermore, dimensional changes after installation of the members in a structure are reduced, eliminating or reducing the cost of tightening bolts and other joint fastenings.

The possibility of designing with stresses based on dry strength of wood. The initial dryness of the laminations permits, where dry conditions prevail in service, the use of design stresses based on the dry strength of the wood. The added strength, as compared with large, one-piece members, depends on the strength property in question but in some cases is quite large (up to nearly 40 percent).

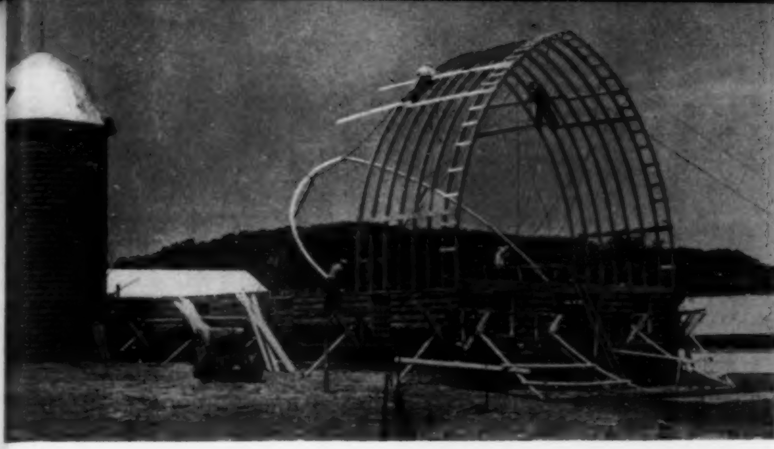
Architectural effects not possible with solid timber. Arches and curved beams of large cross section, which are not possible with solid timber, lend themselves to a variety of architectural treatments and thus open new markets to wood.

The possibility of designing constant-strength members. In designing with laminated wood, it is possible to vary the cross section of the member to fit, more or less exactly, the varying stress requirements at different points.

There are also certain limitations that must be considered in comparing laminated with solid members. The cost of a laminated member is greater than that of a solid member because of the procedures involved in preparing the lumber and in constructing the member. The importance of the glue joint to the integrity of the member necessitates special equipment, facilities, and skills not needed to produce solid members. Also, large curved members may be difficult to ship by common carriers.

Early Use in Laboratory

One of the early applications of glued laminated wood arches was essentially coincident with the beginning of research on this subject at the U. S. Forest Products Laboratory. Laminated arches of two types —solid cross section and box section— were used in an auxiliary building constructed in 1934 on the laboratory grounds. Since its construction, this building has served with a



ALAN D. FREAS, A.M. ASCE

Engineer, Forest Products Laboratory

U. S. Department of Agriculture, Madison, Wis.

Use of laminated rafters for farm building is among new and important uses of laminated timber construction.

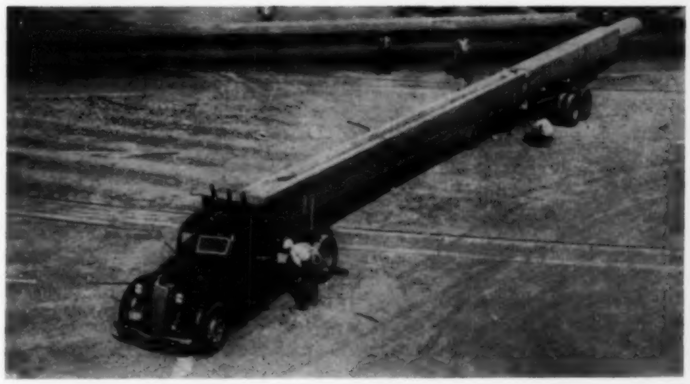
timber permits flexibility of design

minimum of maintenance in roles varying from storage building to office building.

Laminated arches now have many applications, ranging from drill halls, hangars, and industrial buildings to churches, school gymnasiums, and auditoriums. Such buildings employ arches of fairly heavy cross section at moderate and large spacings. Another, and increasingly important, use is in farm and small industrial buildings, where arches of small cross section are used at close spacing.

Laminated construction is increasingly important because it is capable of furnishing structural members of sizes now difficult or impossible to procure in solid form. For example, dredge spuds 30 x 30 in. in cross section and 85 ft long have seen service on the Columbia River. Unusual conditions of a highly humid and acid atmosphere in the dye room of a knitting mill precluded the use of steel trusses or timber trusses with metal connectors because of rapid corrosion. For that construction, laminated beams 24 x 36 in. in maximum cross section and 80 ft long, glued with a highly moisture-resistant glue, were used.

The railroads have long been large users of structural timbers. Because of the difficulty of procuring solid timbers in the large sizes frequently required, they have become interested in laminated construction and have installed laminated members in bridges in California, Texas, West Virginia, and Virginia—and possibly in other states. One of the early installations is a bridge near Alexandria, Va., employing laminated caps, posts, and stringers. To increase the bearing capacity of the caps, a number of oak laminations was used on the outside.



Glued laminated dredge spud, 30 x 30 in. in cross section and 85 ft long, indicates almost unlimited sizes available in laminated timber.

Adhesives and Fabrication

While the primary purpose here is to discuss the engineering-design phases of glued laminated lumber, it seems necessary to discuss, at least briefly, problems in the choice of adhesives and in fabrication. The best efforts of the best designers are of little avail if there are errors in fabrication.

Obviously the bond between the laminations is of primary importance. Without that bond, there would be no structure, but only a group of laminations incapable of serving a useful structural purpose. It follows, then, that an adhesive must be chosen that will furnish such a bond, not only initially, but over a period of years in service. There is, apparently, a reluctance among engineers to have faith in any structure that depends upon glue for its structural integrity. Where this is true, experience has been limited to the older woodworking glues, such as are commonly used in furniture. Many such adhesives will, under adverse conditions, fail completely.

The adhesive industry has made many advances, so that, today, there is a wide range of adhesives available to satisfy very nearly any service condition from mild to extreme. Furthermore, these adhesives are far beyond the laboratory and are in rather wide practical use. Perhaps the most important of the new adhesives, from the standpoint of the structural laminating industry, are the resorcinol resins and the mixtures

Highway bridge of 103-ft span is supported by four glued laminated arches. Treatment with preservative salts was carried out before assembly, but in case of nearby laminated timber arch, creosote was applied after gluing.

or blends of phenol and resorcinol resins. On low-density species, resorcinol-resin adhesives may be cured adequately for many purposes at room temperatures. Phenol-resorcinol blends and resorcinol resins on high-density species require curing at elevated temperatures if the laminated item is to withstand severe service.

Proper selection of an adhesive, however, is only one step in insuring a good glue bond. The best glue, improperly used, may prove a complete disappointment. Adequate techniques of use involve a variety of factors. Among the more important are: uniform seasoning of the lumber and surfacing of laminations; proper mixing and spreading of glue; adequate and uniform application of pressure; and proper curing of the glue, including proper temperatures and time under pressure as well as adequate control of the relative humidity during curing. The variety and character of these factors will generally require special plant equipment and special skills. Ordinarily, this will preclude on-site fabrication, particularly for important structural members.

A question may well be raised as to the fatigue resistance of glued joints, particularly for railroad use. The evidence on this point is reassuring. A series of fatigue tests, including tests both for shear along the glued joint and for tension perpendicular to the glued joint, produced no evidence that the joint tended to deteriorate from fatigue any faster than the wood around it.

Assignment of Working Stresses

In general, methods of structural analysis applicable to structures of other materials are applicable also to structures of laminated wood. The assignment of the correct working stresses, however, involves special considerations, some of which are common to all timbers and some peculiar to laminated members.

In timber design, it has been the practice in the past to assign "basic stresses" to the various species and to compute working stresses for particular grades by multiplying the basic stress by a factor called the strength ratio. The basic stress represents, essentially, the working stress applicable to a defect-free piece. It is derived from the average properties of the species by applying factors that adjust laboratory test results to actual conditions of use. The strength ratio represents the proportion of the strength of a defect-free piece that remains after taking into account the effect of strength-reducing features. In developing working stresses for laminated members, the same system is used.

Basic stresses for laminated timbers under service conditions involving high moisture content are the same as for solid timbers, that is, they are based on the strength of wood in the green condition. One of the advantages of a laminated member is that it can be made of laminations small enough in cross section to be seasoned readily before assembly and thus to form a member seasoned throughout and free from the tendency to check and distort after erection. Obviously, such a member also may be sufficiently dry throughout to justify the use of stresses based on the higher strength of dry material, but only if the conditions of service are such as to maintain a low moisture content in the member throughout its service. Accordingly, the Forest Products Laboratory recommends a second set of basic stresses for structures that will see service under dry conditions.

Lamination Quality

The same characteristics, such as knots and cross grain, that reduce the strength of solid timbers will also affect the strength of laminated members. There are, however, additional factors peculiar to laminated construction that must be considered. A strength-reducing feature, such as a knot, must necessarily have less effect on strength if it is located in a region of low stress, such as that near the neutral plane of a beam, than if it is located in a region of high stress. Tests have confirmed the view that substantial amounts of relatively low-grade material can be placed in the central portion of a beam or arch without serious effect on the overall strength. Thus, even though some of the laminations in a beam made of high-grade lumber are replaced by laminations of a lower grade, it is possible to maintain a considerable proportion of the strength of the beam. Conversely, the strength of a beam of low-grade laminations can be improved by substituting a few high-grade laminations at the top and bottom of the beam.

Obviously, it is unlikely that large knots will tend to concentrate at the critical section of a laminated member, and therefore the dispersion of knots in laminated members should have an advantageous effect on

strength. Some proposed design procedures assign a more or less arbitrary evaluation to this effect. It is possible, however, with sufficient knowledge of the occurrence of knots within a grade, to establish mathematical estimates of this effect for members containing various numbers of laminations. Allowable design stresses computed in this manner are somewhat higher than for solid timbers of comparable grade. Cross-grain requirements, therefore, must be more rigid than for solid timbers in order to justify these allowable stresses.

Joints Evaluated

In laminated members of considerable size, pieces of lumber must be joined end to end to provide laminations of sufficient length. These joints are an important factor in determining the strength of laminated members. Since stress cannot be transferred across a butt joint, such a joint represents an ineffective area, and additional cross section must be provided to compensate for it—a wasteful procedure. What is not so obvious is that a butt joint is a serious source of stress concentration, not only with respect to shear stress in the interlaminar joints adjacent to it, but also with respect to longitudinal stress in the adjacent laminations. Butt joints are not commonly used in important structural members, but where they are, account must be taken of both the ineffective area they represent and their stress-concentrating effects.

On the other hand, scarf joints, in which the sloping ends of two pieces are joined with glue, are effective means of joining the ends of pieces to form laminations of the required length. Even so, experience and research have indicated that scarf joints should not be considered fully effective. Definite reductions in working stresses are recommended when scarf joints are used, the reduction being greater for the steeper scarf slopes. For example, it is recommended that, when stressed in tension, a scarf joint having a slope of 1 in 12 be stressed to not more than 90 percent of the stress that would be permitted in an uncut lamination. At a slope of 1 in 5, the corresponding percentage is only 65 percent.

Edge joints, which may be required to provide sufficient width, are generally of little importance from the standpoint of strength, except in vertically laminated members, where they have an effect on shear resistance. In horizontally laminated members, they are frequently not glued.

Stresses Induced by Bending

Bending of laminations to a curved form induces stress in them. Often a calculation of the stress induced indicates that it is well up toward, and sometimes beyond, the proportional-limit stress of the material. From this it would appear that the stress that may be permitted in the finished member would be considerably reduced. Tests have shown, however, that this stress is largely relieved, and that the reduction in working stress is generally moderate.

A related factor, which is not encountered in ordinary timber design, must be considered when deep, sharply curved members are involved. It will be recalled that, in such members, the stresses computed by ordinary methods for flexure members will be in error by an amount depending upon the ratio of center-line radius to depth of member. In many curved laminated members, this factor will be of little or no consequence and can be neglected. In other members, however, the error may be of considerable magnitude. For example, at a radius-depth ratio of 6, the error will be about 5 percent, but at a radius-depth ratio of 3, it will be about 11 percent, with rapidly increasing percentage errors as the ratio of radius to depth becomes smaller. Since the relation of error to ratio is readily plotted, such a plot might well be kept handy and used in designing for a quick check as to whether the error involved in the use of ordinary formulas is of consequence.

Stiffness Considerations

Contrary to the usual practice in designing with solid timber, research has shown that, with laminated material, the modulus of elasticity decreases with decreasing grade. It appears, however, that the reduction will generally amount to only a few percent, so that, in structures where deformation is not critical, the basic value of modulus of elasticity may be used. Where deformation is critical, and more refined values of modulus of elasticity are required, methods are available for evaluating the required reduction.

More important than the minor adjustments required for grade is the necessity for taking into account, by one means or another, the increasing deflection, or sag, that takes place with time under continued load. The use of values of modulus of elasticity recommended in ordinary tables of basic or working stresses gives only an average value of immediate deflection. To take account of increasing deflection, when this must be limited, it is common to use half the value of modulus of elasticity in the calculation of immediate deflection, thus limiting the immediate deflection to half of that expected over a long period. Experience has indicated that the long-time deflection will be about twice the immediate deflection.

Height and Form of Bending Members

It has long been known that stresses in wood beams, as computed by conventional methods, are affected by both the form and the height of the cross section. This has led to the development of form factors to be applied to the usual bending equation. The effect of height has heretofore been relatively unimportant, since the depth that could be realized in solid timbers has been limited. In laminated construction, however, this limitation has been removed, and beams and arches of considerable depth are common. Members 2 to 4 ft deep are not uncommon, and one member having a depth of about 7 ft has been projected. Consideration of the effect of height as well as of the form factor thus assumes some importance in the design of laminated construction.

Today, a considerable number of firms are manned and equipped to furnish laminated members in a variety of forms and species for a myriad of uses. Many, too, are prepared to furnish the specialized engineering services required. While the industry is young and is experiencing some growing pains, it is expanding rapidly and its products are daily gaining more general acceptance.

The Southern Pine Association and the West Coast Lumbermen's Association have prepared standards of design and fabrication for softwood laminated members that will be useful as a guide to the purchaser in defining what he can expect from the product. A committee of the American Lumber Standards Committee has under way a similar standard for laminated hardwood for structural uses. Consideration also is being given by the American Lumber Standards Committee to a more fundamental, overall standard for laminated members.

Photographs are used by courtesy of the U. S. Forest Service, Forest Products Laboratory.

(This article is based on the paper presented by Mr. Freas before a wood symposium session presided over by L. J. Markwardt, M. ASCE, at the Centennial Convention in Chicago.)

T. R. HIGGINS, M. ASCE, Director of Engineering, American Institute of Steel Construction, Inc., New York, N.Y.

E. J. RUBLE, M. ASCE, Structural Engineer, Research Staff, Association of American Railroads, Chicago, Ill.

High-strength bolts —a new concept in structural connections

The entire growth of engineering knowledge with respect to metal construction, which plays such an important role in modern living, falls almost completely within the one hundred years that have elapsed since the founding of the American Society of Civil Engineers. Although the use of rivets and bolts in joining metal components had been part of the craftsman's art for centuries, engineering concepts as to the behavior of such joints, by which their strength could be evaluated for the design of structures, were probably first applied in the construction of the Britannia and Conway tubular bridges about the middle of the nineteenth century.

Necessarily in the beginning, these concepts were supported by test data obtained only from very small specimens. Considering the very simple and not altogether accurate testing methods used, it is remarkable that the data agree as well as they do with those of more recent investigators.

It is interesting to note that the contribution to the strength of a joint made by the "friction produced by the cooling of red-hot rivets" was recognized by at least one writer a century ago. He observed that, at working loads, joints acted by friction alone. Nevertheless the classical concept of a riveted or bolted joint almost from the start has been that of adjacent plies loaded in opposite directions and held together by virtue of the shear strength of the fastener.

In the case of riveted connections, resistance to applied loading is generally assumed to take place with little if any slip, because the forging of the rivet has substantially filled the rivet hole. Likewise, the use of turned bolts in reamed holes is assumed to control the slip between the connected parts within tolerable limits, although hole clearances up to 1/50 in. are permitted in fabrication. In connections where slip is of less consequence, it has long been the practice to place unfinished bolts in holes punched or drilled to a size 1/16 in. greater than that of the bolts themselves.

Stress Transferred by Friction

The accepted use of high-strength bolts, prestressed to such tension that friction between the connected parts alone can be relied on to transfer the stress from one member to another, is a development which has taken place in the field of bridge and building construction only within the past five years. Several factors have served to stimulate this development.

In the first place, it was discovered that the use of hardened washers under the nut and the bolt head made possible clamping forces greatly in excess of the best that could be achieved through the shrinkage of hot rivets on cooling. These clamping forces are sustained without significant relaxation even after hundreds of thousands of loading cycles. In the case of bridges and other dynamically loaded structures, the demonstrated superiority of highly prestressed, high-strength bolts in providing a smoother stress path, thus materially improving the fatigue strength of the joint, offers a distinct advantage over riveted construction.

The use of high-strength bolts for the field connections of bridges and buildings involves no retraining of drafting-room or fabricating-shop forces, and no replacement or rearrangement of existing shop equipment and fabricating practices.

Costwise, high-strength bolt construction competes with riveting. The bolts themselves are much more expensive than undriven rivets, but the difference is largely, and in some cases completely, offset by lower installation costs. Even were this not so, the present shortage of riveters in many parts of the United States still would suggest a need for the newer type of fastener, the proper installation of which requires only a minimum of steel worker training.

In the early stages of the investigation covering the use of high-strength bolts, sponsored by the Research Council for Riveted and Bolted Structural Joints, it was realized that laboratory tests conceivably might

not include all the factors affecting their behavior in dynamically loaded railroad and highway bridges. The joints of such structures are subject not only to fluctuation in loading, but also, concurrently, to vibrations of varying amplitude and frequency.

Accordingly, in 1948 the research staff of the Association of American Railroads arranged with several railroads to replace with high-strength bolts more than 1,000 existing rivets in a number of joints of twelve different bridges, where trouble had been encountered in keeping rivets tight because of excessive vibration and other unusual service conditions. In several of these structures maintenance crews had to redrive a certain number of loose rivets each year.

It had been the practice with some of the railroads for the division forces to temporarily replace rivets found to be loose by the bridge inspectors, with ordinary carbon bolts. Eventually these bolts in turn would be replaced by new rivets, installed by the steel-bridge gang when the accumulated number to be driven was sufficient to justify bringing a compressor and riveting equipment to the site. In the meantime it often would be necessary to retighten the temporary bolts since they were incapable of retaining their initial tension for any extended period under the service conditions.

Bolts Hold Where Rivets Fail

In each case included in the field test program, all the rivets in a joint were replaced, one at a time, by high-strength bolts of the same nominal diameter. These bolts have been inspected periodically, and after four years still retain their full clamping force. Meanwhile the rivets in similar joints on the same structures (sometimes at the other end of the same member) have continued to work loose.

In one case, where common washers were originally installed with the high-strength bolts, the bolts did not stay tight. However, ever since the common washers were replaced with hardened washers, nearly four years ago, the bolts have maintained their initial prestress.

Some bolts were installed in jagged holes which had become enlarged as a result of the frequent backing out of loosened rivets. Wherever two hardened washers were placed under the head and nut of these bolts to prevent deflection in the enlarged holes, the bolts retained their full clamping force.

In all these installations the friction created in the threads by the high initial bolt tension alone was sufficient to prevent any loosening of the nut. No self-locking type of nut or washer was used, and the threads were not burred after the nuts had been tightened.

In general, the bolts used in this program were tightened to develop a tensile stress on the mean thread area of 72,000 psi (equivalent to approximately 85 percent of the specified yield-point stress). The bolts in several of the joints, however, were deliberately tightened well beyond the yield-point stress. The excessive amount of prestress did not appear deleterious. These bolts have been functioning satisfactorily for more than four years without exhibiting any visible evidence of damage or impaired clamping force.

To study the use of high-strength bolts in cold climates, existing rivets were replaced by such bolts in several floor-beam hanger connections on riveted bridge trusses where the temperatures fall to at least −40 deg F. The bolts have now been in place for two winters and have proved entirely satisfactory.

The cost advantage of high-strength bolts on bridge maintenance is quite apparent. Transportation of driving equipment, per redriven rivet, is expensive because of the limited number and scattered location of the rivets involved, even when the riveting operation is postponed as long as possible by the temporary substitution of ordinary bolts. The required tightening specified for high-strength bolts, on the other hand, can be achieved with manually operated wrenches.

Pneumatic Wrenches Control Tightness

Although manual installation is the most economical method when only a few scattered bolts are required at some remote site, it would be unnecessarily expensive for general use on building construction. Here the use of air-impact wrenches not only reduces the required physical effort to a minimum and saves considerable time, but also introduces a simple yet remarkably effective bolt tightening control.

Pneumatic-impact wrenches are only slightly heavier than the hand hammers used for driving rivets of the same nominal diameter. They need but a single operator and are about as portable as riveting hammers.

The torque required to tighten the nut to the desired bolt tension, after the air motor has spun it down until it first seats, is provided by a very rapid succession of blows delivered normal to radial lines passing through the bolt center-line. Blows are delivered simultaneously on opposite sides of the bolt; their reactions are balanced, and the physical effort required of the operator is considerably less than that involved in driving rivets. Furthermore, this effort need be sustained for only a fraction of the time necessary to drive a rivet.

At a normal operating air pressure of, say, 80 to 90 psi, about five seconds is required after the nut first seats, before it has been turned to the desired tightness. Depending on the size of the bolts being installed, as many as six wrenches can be served by a single 160-cfm compressor.

This relationship of air pressure to nut-tightening effort has provided the most effective bolt tension control thus far developed. By inserting a pressure regulator in the air supply line to each wrench, the wrench can be made to "stall" when the desired bolt tension has been achieved. Naturally, at the reduced pressure the tightening time is somewhat extended—from perhaps five seconds to about ten seconds, depending on the size and the type of wrench, which places less of a premium on operator reaction time for the controls. At the point of "stall" the wrench continues to impact but lacks the power to deliver a substantially larger torque. This point can be detected by a noticeably heavier vibration in the wrench. At this point there is no visible turning of the nut, and the tightening socket on the wrench tends to recoil after each blow.

The wrenches are capable of tightening bolts of more than one nominal diameter, although more than one wrench size would be required to operate effectively over the entire range of bolt diameters encountered in bridge and building construction. Even for any one given diameter, the amount of torque necessary to produce a specified bolt tension can vary somewhat, depending on the condition of the threading.

Table III, in the Research Council's Specification for the Assembly of Structural Joints Using High Tensile Steel Bolts, attempts to correlate required bolt tensions with corresponding equivalent pound-feet of torque, for various bolt sizes. A footnote states that the torque values are experimental approximations.

Several devices have been developed whereby the air pressure at the wrench can be adjusted so that the desired bolt tension is provided without reference to any intermediate measure of torque. Where these devices have been used, operators with no prior experience have been able to

consistently obtain entirely satisfactory results. Using this technique, all the variables which affect bolt tightness—wrench capacity, bolt size and length, and condition of the threads—are brought into proper balance in a single operation.

One device permits the bolt to be tightened against the parallel faces at the ends of a hollow cylinder, through which the bolt has been inserted. The clamping force delivered to the cylinder by the tightened bolt can be read by electric resistance strain gages and an indicator.

Another device is so constructed that a bolt of the size and character to be installed at the site is tightened against an enclosed volume of fluid, the resulting pressure in which, converted to equivalent bolt tension, is read directly on a pressure gage.

Bolts tightened with impact wrenches adjusted by these devices have been found to provide consistently accurate amounts of prestress, when checked with a torque wrench. For this reason the concern of inspectors has been more with the calibration of the impact wrenches, and subsequently with maintaining it throughout the day, than with spot checking the finished work with a torque wrench.

Some misunderstanding has been reported as to the intent of Section 4(*b*) of the Council's Specification. Attempts have been made to restrict the bolt prestress to precisely that specified in Table III, no more and no less. The tabulated tension values, 90 percent of the minimum specified elastic proof load of the bolts, are calculated to develop nearly the maximum clamping force that can be expected of the bolts. Although no useful purpose is served when a bolt is strained beyond rather than up to its elastic limit, numerous field and laboratory tests have indicated that no damage is sustained by bolts tightened well beyond this point. They still are capable of providing a clamping force limited only by the elastic properties of the bolt. Since the minimum specified breaking strength of the bolts is not reached until a tension in excess of 150 percent of the values given in Table III has been applied, too meticulous attention to an upper limit of prestress is unnecessary and only serves to increase the erection cost.

The use of a pneumatic impact wrench does entail some noise. During the short interval when the wrench is spinning the nut into bearing against the hardened washer, the noise from the wrench ordinarily would be masked by the level of noise incident to other construction operations. In fact, the much sharper sound which follows when the nut has been seated may be obscured by many common construction noises. The maximum noise level of the wrenching operation has been described as approximately one-half that of an ordinary riveting hammer. Its duration likewise is only half that required to drive a rivet. It is significant that many of the projects using high-strength bolts which have already been completed, or which are contemplated for construction in the immediate future, have been additions to hospitals where much study was given to this aspect of the problem.

Few building connections are subject to the dynamic loading and vibration which are characteristic of railway and highway bridges. Hence the superior fatigue strength which is characteristic of connections made with high-strength bolts loses much of its appeal in ordinary building construction. Nevertheless, to relieve pressure on the currently inadequate supply of trained riveters, economically and with a minimum of change in existing practices, the high-strength bolt has much to offer, as is evidenced by the number of structures which have been, or are being, erected using such bolts in the short time since their possibilities were first fully realized.

Bolt tension can be effectively controlled by regulating air supply to wrench. In this way wrench can be made to "stall" at desired bolt tension. Point of "stall" is indicated by heavier vibration of wrench, while nut appears to stop turning.

Bolts Used in Construction

One of the first buildings to be constructed utilizing substantially the same techniques as are now recommended by the Council was a 14-story hospital for the University of Illinois, at Urbana, designed by Holabird & Root & Burgee of Chicago. At that time the Specification for Quenched and Tempered Steel Bolts, serial designation A-325, had not been accepted by the American Society for Testing Materials, and somewhat stronger and more expensive bolts were used in lieu of those now recommended. These bolts had to be manufactured to order, and delays were experienced in delivery so that some additional erection cost was involved. Nevertheless, it has been reported that the bolts cost only between $6.00 and $7.00 more per ton of steel erected than field rivets would have.

Also included in recent bolted hospital construction were the first eleven stories of a 21-story addition to the Mayo Clinic at Rochester, Minn., designed by Ellerbe & Co. of St. Paul; a 21-story building for the Mayo Memorial Medical Center at the University of Minnesota in Minneapolis, designed by C. H. Johnston, also of St. Paul; the 15-story General Hospital for the University of Oregon Medical School at Eugene, designed by Lawrence, Tucker & Wallmann of Portland; and the 13-story Johns Hopkins hospital building in Baltimore, Md., designed by James R. Edmunds of Baltimore.

A complete tabulation of all the structures assembled with high-strength bolts in the past few years since their use was first proposed is not possible. One or two representative installations should suffice to give a fair picture of the increasing

popularity of this newest of fastening techniques.

The new Aluminum Company of America plant at Sandow, near Rockdale, Tex., comprising some twenty-five industrial shed-type buildings, will require approximately 100,000 high-strength bolts. The buildings, designed by the Aluminum Company's own engineering department, are one story high. The roof trusses span 60, 80, and, at times, 100 ft.

Some 10,000 tons of structural steel will be required to complete a large jet-engine manufacturing plant for the Chrysler Corporation at Utica, Mich. The project also includes a much smaller three-story frame for a powerhouse. Plans for the construction were prepared by Albert Kahn, Associated Architects and Engineers, of Detroit. All primary connections will use A-325 bolts. Secondary connections such as purlins and sash angles will use ordinary unfinished bolts, as would have been the case had the principal connections been riveted.

The one-story building is so large that considerable planning was justified in organizing the erection forces for the new bolting technique. The steel was erected with one pin and one fitting-up bolt in each connection, in the usual manner. The final bolts were installed by steel workers whose task was completed when these bolts were made snug with an ordinary hand wrench.

Since there were a great many repetitions of more-or-less identical connections, each man was assigned the job of placing the bolts in a single type of connection. Tightening gangs, each consisting of two men who did nothing but bring the bolts up to the specified prestress using impact wrenches, followed immediately behind. Most of the connections could be reached without scaffolding. It was found that it took three to four men to keep ahead of a tightening gang. The average production per man, counting all those engaged in the work, was in the order of 150 bolts per day. Two tightening gangs, confining their activities entirely to this one operation, installed as many as 3,100 bolts per working day.

When several bolts are required in a single connection, the tightening of the later bolts often increases the total clamping effect on the connection to such an extent that the first bolts tightened often have to be retightened. On this project it was found that connections with as many as seven holes in a single row could be quickly brought up to the proper tensions by tightening the center bolt first, then proceeding from the top hole down to the bottom one, thus giving the center bolt a second treatment halfway through the operation.

Some 5,000 high-strength bolts were used in the construction of two sections of a viaduct—one section 550 ft and the other approximately 700 ft long—on the freight line of the Union Railroad Co. over Turtle Creek in East Pittsburgh, Pa. This viaduct, consisting of four lines of plate girders supporting 18-in. transverse floor beams spaced 2 ft 6 in. on centers, carried track ballast laid on a steel plate deck. High-strength bolts connected the floor beams to the longitudinal girder.

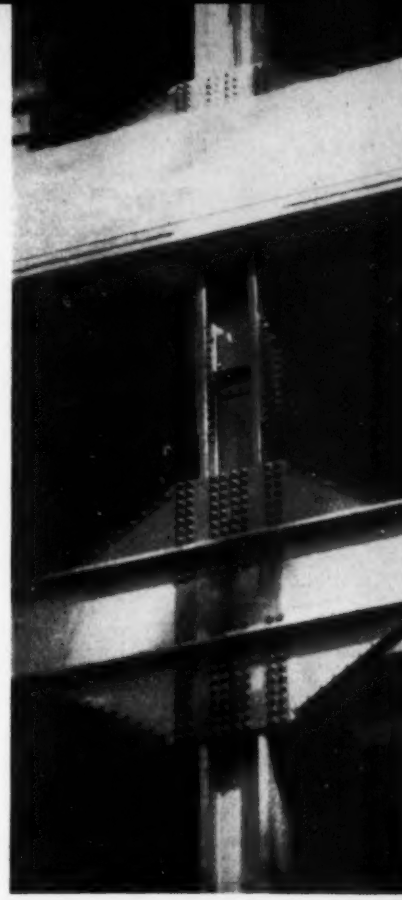
More than 150,000 high-strength bolts were required for the primary connections in the General Motors Corporation's huge Buick-Oldsmobile-Pontiac assembly plant at Arlington, Tex. This project, providing 1,250,000 sq ft of floor space, consists principally of 45 x 45-ft, 45 x 90-ft, and 90 x 90-ft bays of one story truss-and-column framing.

Part of the building is two stories high. Overhead traveling cranes are supported on the building frame as is also the case in the Aluminum Company building at Sandow. Plans were prepared by the Argonaut Realty Division of General Motors Corporation. In the invitation to bidders, fabricators were instructed to quote both on the basis of field riveting and on the basis of high-strength bolts. The successful low bidder submitted the same price for both methods of field fastening.

On some of the projects mentioned, cost comparisons were prepared on the various methods of making field connections. On others no detail studies were attempted, since some increase in cost would have been tolerated in the interest of expediting construction. Where comparisons have been attempted, any differences found generally have been so small that they could be verified only by actual performance records on two otherwise identical projects.

Research on Bolts Continued

The elimination of one item of expense, having to do with shop paint at the contact surfaces of connections assembled with high-strength bolts, is currently being studied under the Council's research program. Section 3(*c*) of the present Specification requires that faying surfaces be free of paint, lacquer, oil, and all other materials which would interfere with the development of friction between the parts, because laboratory tests have



First eleven floors of 21-story addition to Mayo Clinic at Rochester, Minn., were constructed with high-strength bolts. Noise reduction secured by use of such bolts may be an important consideration in hospital construction.

indicated the possibility of a gradual slip under long-sustained loading, no doubt caused by a shearing action within the body of the paint film. As in the case of similar provisions usually invoked where connections are to be field welded, it is necessary to note on the shop drawings all locations where shop paint is to be omitted. This drafting-room operation, coupled with shop expense involved in marking limits for shop painting of the steel parts and some expense in "touching up" the shop coat in the field after erection, of course costs money. The expense, although not great, constitutes a challenge. Some solution to the problem, other than the omission of shop paint, surely will be found.

To date the only specification recommendations published by the Council are concerned with the case where shear must be transmitted across a joint and where slip of any consequence generally is not permitted. For those connections where slip can be permitted, such as the

(*Continued on page 255*)

California's all-welded viaduct points way to improved design

The Centennial of Engineering would not be complete without consideration of the great advance that has taken place, particularly in the past few years, in the field of welded structural steel fabrication. Not many years ago, welding on major buildings and bridges was limited to secondary details only. Today large bridges and some buildings are using welding to fabricate not only main stress-carrying connections and splices but also heavy girder and column sections from rolled plates.

In California three factors during the past ten years have added impetus to the welding of structural steel bridges:

1. The shortages of steel caused by World War II and the present Korean War.
2. The great increase in the knowledge of the physical and chemical phenomena surrounding the welding of structural steel, along with the great improvements in welding equipment and technique.
3. The large expansion of highway bridge construction, coupled with the structural engineer's persistent desire to search out better and more economical methods of bridge construction.

Because of the war in Korea, California found that its allotment of steel was not sufficient to advertise all its needed projects, the allocation of rolled shapes being particularly short. The design of one structure which first required riveted girders and rolled beams was changed to specify girders and beams fabricated from rolled plates. In redesigning the structure, the beams were made to act compositely with the slab, further reducing the amount of steel needed. In all, 9 riveted girders 77 ft long, and 138 rolled beams 44 ft long, were revised to 3 welded plates. The change to composite construction and welded plates reduced the total amount of steel required by 200,000 lb and made it possible to advertise the project at that time.

The successful contractor's bid for structural steel was $0.135 per lb and the average bid was $0.153 per lb, whereas the low bid was $0.127 per lb and the high bid, $0.180 per lb—not including painting. Although these prices were very reasonable, it is likely that had the allotment allowed the use of rolled beams a somewhat lower price would have been possible.

In San Francisco, the great San Francisco–Oakland Bay Bridge collects from and discharges into the crowded city streets of San Francisco from 80,000 to 90,000 cars per day. From the south side of San Francisco the Bayshore Freeway carries another 100,000 cars per day to and from the city streets. The Division Street Interchange will connect these two great arteries of traffic and provide for the interchange of traffic into the city at more convenient points. In addition, it will allow an uninterrupted flow of through traffic, thus keeping thousands of cars off the already crowded city streets.

Because this great freeway viaduct and interchange structure (Fig. 1) is being built of welded steel columns and girders in six different units and contracts, it presents an ideal basis for discussion of the latest developments in welded steel bridge construction. The stage method of construction permits possible improvements in the plans and specifications for each succeeding contract, taking advantage of any experience gained as the work progresses.

Design

The design of most of the spans of the Division Street Interchange in the 50- to 60-ft range was governed by economy and esthetics, except where the structure crosses railroads and city streets. At these locations span lengths were determined by clearance requirements.

To reduce the number of columns to a minimum and to produce good esthetic qualities, the bent supports for the steel superstructure are fabricated of structural steel. These bents have one, two, or three columns. There are a few single-column, channel-shaped bents.

Preliminary studies and designs which were started in the summer of 1950 by the Bridge Department of the California Division of Highways indicated that a structural steel design would be the most satisfactory for two reasons:

1. Structural steel was found to be the most economical because its light weight would considerably reduce the cost of the foundations, which are to be supported on piles up to 90 ft long.
2. Because of the many railroad and busy city street crossings, it was desirable to eliminate the need for falsework.

The choice between riveted and welded structural steel was made both for esthetic and economical reasons. For instance, most of the spans were in the 50- to 60-ft range, which called for rolled-beam sections. Where longer spans were needed because of clearance requirements, it was desirable to maintain the same rolled-beam appearance and to provide for the longer spans without too much increase in the depth of the beams. This result could best be obtained by welding. From the

L. C. HOLLISTER, M. ASCE

Engineer of Design, Bridge Department

California Division of Highways

Sacramento, Calif.

Freeway and Division Street Interchange structure are superimposed on aerial viev San Francisco, which faces almost due north toward heart of business district. Via connects with San Francisco–Oakland Bay Bridge, shown in upper right-hand cor

FIG. 1. Changing roadway widths at "on" and "off" ramps, sharp skews, curved alignments with superelevations are features of Division Street Intercha

standpoint of economy, welding appeared to have the edge over riveting for several reasons.

First, the beams were made composite with the concrete floor slab, which required welding of the shear connectors. In addition, the changing roadway widths, skews, and curved alignment made welding of the secondary connections for diaphragms and stiffeners more desirable. Since a considerable amount of welding would be required in any event, it would be reasonable to go one step further and make the interchange an all-welded structure, thus conserving steel. For the built-up girder sections, the saving in steel amounted to 15 to 20 percent because of the saving in net section and the more efficient placing of steel to provide the necessary moment of inertia.

A further saving in structural steel was noted in the design of the caps and columns, amounting to 20 to 24 percent in the heavy steel caps, and to 12 to 15 percent in the columns.

The structure was designed for H20-S16 live load in accordance with the bridge design specifications of the American Association of State Highway Officials. Working stresses were 1,000 psi for concrete, 20,000 psi for intermediate-grade reinforcing steel, and 18,000 psi for tension in structural steel. However, in the final design for Unit 1 there was one exception to these working stresses. Plates thicker than $1^1/_2$ in. had a reduced working stress of 15,000 psi, as explained later in this article, under the discussion of specifications. In the remaining units of the project working stress for steel remained at 18,000 psi for all thicknesses.

The welded details were made to conform to the Specifications for Welded Highway and Railway Bridges of the American Welding Society (AWS).

The spans are all simply supported and made composite with the reinforced-concrete roadway slab. The composite action considerably reduced the size of beam required, and in addition increased the stiffness against live-load deflection. Rolled beams 36 in. deep are used for some spans up to 85 ft. Cover plates are welded to the lower flanges of the rolled beams for spans from 70 to 85 ft.

Composite welded girders are used for all spars from 85 ft to the maximum of 117 ft. These girders are of standard three-plate design, with flange plates welded to the web plate. Web stiffeners are plates welded to the web with continuous fillet welds. Stiffeners are omitted from the outside face of exterior girders to retain the same smooth surface appearance as the rolled beams. The web plates of the welded girders are kept at a minimum depth so as to avoid too great a change from the shorter rolled-beam spans to the longer welded girder spans. Web plates vary from $42 \times {}^3/_8$ to $54 \times {}^3/_8$ in., and flange plates from $12 \times {}^3/_4$ to $22 \times 2^1/_2$ in.

Because the adjacent property owners always object a great deal to overhead construction within a metropolitan area, the number of columns and the appearance of the bent supports are most important. Therefore, in the design of the structure there was a definite attempt to reduce the number of columns to a minimum within practicable limits, and to make the supporting bents as attractive as possible.

Ramps carrying four or more lanes of traffic are supported by bents with two or three columns. T-shaped single-column bents are used for most of the two-lane and three-lane roadways, and in some instances for four-lane roadways. The T-bents proved very effective in crossing many of the streets and out ramps without resorting to the skewed spans which are usually quite objectionable not only from the design standpoint but also from that of esthetics.

At some locations, where sharply curved ramps cross over other parts of the structure, it was found that bents with heavy outriggers, or single-column bents with eccentrically loaded columns, would be required. Because of the unfavorable appearance of outrigger construction, a channel-shaped bent was chosen (Fig. 2).

On the westerly leg of the structure, which extends toward the Golden Gate Bridge, the upper deck is composed of two 36-ft roadways with a median strip. Below the upper deck is Thirteenth Street, which will be preserved as a city street. The bents for this part of the interchange (Units 2 and 4) are composed of three columns. Column sections for the two- and three-column bents and T-bents are somewhat similar in makeup to the one shown in Fig. 2. Web plates for the different column sizes vary in width from 36 in. to 120 in., depending on column height, and magnitude and eccentricity of load.

The makeup for the various column sections was given considerable study from both the esthetic and fabricating standpoints. Preliminary designs were discussed with welding interests to determine the practicability of welding. Reviews were also made by the leading fabricators on the Pacific Coast to determine the most satisfactory makeup from a fabricating standpoint.

No special difficulties have arisen so far. However a few points are worthy of consideration on future projects and on the remaining units of this project. They are:

1. The $36 \times \frac{3}{8}$-in. web plates of the two-column bent section, although satisfactory from a design standpoint, could have been heavier to impart greater stiffness for handling during fabrication.

2. Because the 6-, 8-, and 12-in. side plates of the columns were welded off center, they warped. Such plates must therefore be cambered the correct amount before welding or straightened after welding. Built-up welded designs should maintain as much symmetry as possible in welding about each piece, but it is realized that this is not always possible.

3. Columns and caps must be shipped to the job separately and welded together in the field during erection. Since the 6-, 8-, and 12-in. side plates of the column sections extend up to and engage the cap, the upper end of the column will be somewhat vulnerable to damage during shipping. The Bethlehem Pacific Coast Steel Co. is therefore providing temporary diaphragms and blocking to protect the top members of the columns.

The welding of caps to the columns is practically the only field welding specified in the design. Because welding conditions in the shop are so much more favorable for reliable welds, a definite attempt was made throughout the design to avoid the necessity of field welding.

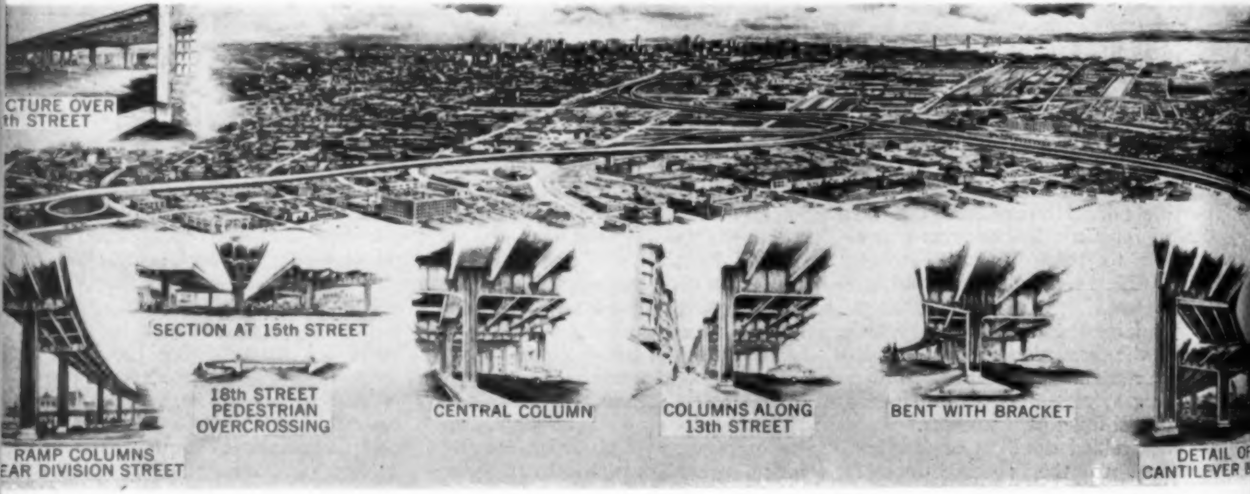
At the various footing locations, concrete, steel, and timber piles of various types will be used, depending on length and soil conditions. Sufficient piles of each type will be test loaded to insure the following design load capacities:

Design	Load
Treated timber, 14-in. minimum butt	24 tons
Treated timber, 13-in. minimum butt	22 tons
Composite concrete and timber	24 tons
10-in. standard steel pipe, concrete filled	46 tons
$15\frac{1}{2}$-in. cast-in-place steel-shell concrete piles	46 tons
16-in. precast concrete piles	46 tons
10-in. steel H-piles	37 tons
12-in. steel H-piles	46.75 tons

Table I shows the approximate amounts of steel required and the ap-

Below: Architectural sketch of Division Street Interchange shows its general location. Close-up sketches give details of various parts of structure.

Right: Fig. 2. Channel-shaped bents were used instead of unsightly outriggers to make interchange structure attractive esthetically. Typical details are shown.



proximate cost for the six units of the project.

Specifications

The preparation of a set of specifications for the economical construction of major bridges using all-welded structural steel is far from a routine procedure. For instance, the American Society of Testing Materials (ASTM) is still working on the problem of a special structural steel completely suitable for welding. Standard dimensional tolerances have not been established for beams and columns fabricated by welding. The conditions under which it is necessary to preheat and postheat have not been definitely established. Standard methods of shop inspection and laboratory testing are still in the formative stage.

Welding is an important part of the science of metallurgy and should be so considered when used in the design of structures. It is therefore essential that the structural engineer be familiar with that part of metallurgy which deals with the properties of metals as they are heated. Since all is not yet known about the metallurgy of welding, it may be necessary for the engineer in his design to compromise between the ideal materials and procedures and the materials and procedures that are economically available.

During the welding process the steel is heated to approximately 2,800 deg F. Then the rapid quenching by the colder metal near the area of the weld hardens or embrittles the steel as it cools, depending on chemical composition and rate of cooling. Most recent literature and tests point to the fact that this embrittlement is the most important characteristic to be guarded against in preparing specifications.

Embrittlement is discussed in terms of notch sensitivity or transition temperature. Each type of steel has a certain transition temperature at which it changes from a ductile, highly impact-resistant material to a more brittle, less impact-resistant material. This transition temperature is determined by making V-notch Charpy, and other tests under various temperatures until the temperature at which there is a decided drop in impact resistance, or energy absorption, is determined.

It is generally believed that the area near the weld which tends to become brittle is the critical section. Every effort should therefore be

TABLE I. Approximate Cost and Amount of Steel Required for Division Street Interchange, San Francisco, Calif.

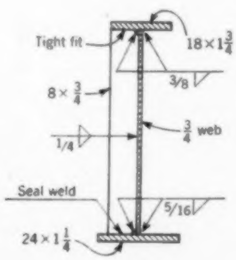
Unit	Bid Date	Contractor	Fabricator	Approximate Cost of Unit	Tons of Structural Steel	Tons of Welded Plates	Unit Bid,‡ Price per Lb of Steel
1	6/13/51	Chas. L. Harney, Inc., San Francisco	Bethlehem Pacific Coast Steel Co.	$3,044,750	4,885	1,550	0.152
Bayshore Freeway*	3/12/52	Fredrickson & Watson M. & K. Corp.	Judson Pacific Murphy Corp.	$1,386,350	325	265	0.170
2	2/13/52	Chas. L. Harney, Inc.	....	$ 458,100	Substructure contract No structural steel		....
3	5/14/52	Guy F. Atkinson Co.	Judson Pacific Murphy Corp.	$2,987,000	6,100	2,600†	0.131
4	7/2/52	Chas. L. Harney, Inc.	....	$2,911,364	6,800	4,710	0.131
5	1953	....	....	$6,250,000	6,200	1,900	....
6	1953	....	....	$ 900,000	1,775	570	....

* One bridge, three-pedestrian outer crossing.

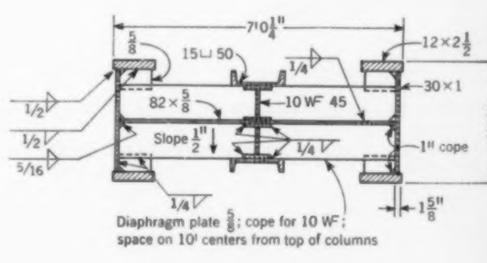
† Specifications allow 36-in. rolled beams to be fabricated by three welded plates, which could raise from 2,600 to 5,800 tons.

‡ Unit price per pound of structural steel includes special steel and A7 steel, but does not include sandblasting or painting.

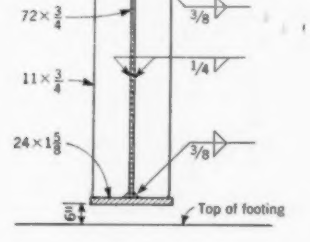
Channel-shaped bents

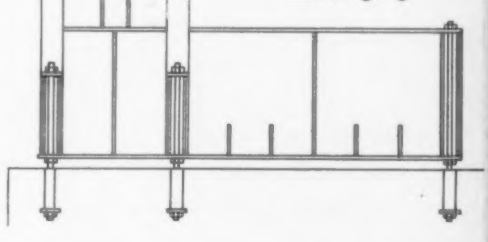


Cap section



Column section





made to select proper steels and to adopt such preheating and cooling processes as will avoid this embrittlement. Although this theory seems to be the general trend of most of the thinking today, there is still the possibility that cracks are initiated in the weld metal.

Since the design required the use of heavy plates for the built-up girders, columns, column caps, and grillages, it was apparent that structural steel under the ASTM A7 specification would not be entirely satisfactory. Therefore, a series of discussions was held with the metallurgical and mill authorities of the major steel companies, and with the best informed men of the welding industry, to work out a satisfactory specification for the chemical and physical properties of the steel for the thick plates, and also to decide on the proper amount of preheating and postheating.

The problem seemed to be somewhat complicated because of the restrictions on steel and the critical shortages of such elements as aluminum, chromium, vanadium, and nickel which are used to produce weldable steels with desirable strengths and good impact resistances at low temperatures. Some of the existing steels considered were: American Bureau of Shipping steel for hulls, ASTM A242 low-alloy structural steel, ASTM A201, ASTM A284, and ASTM A285.

Because the plate for this project was as much as $2^1/_2$ in. thick, and a yield point of 33,000 psi was desired, some of these steels did not seem acceptable.

In any event Unit 1 of this project was finally advertised with the following specifications for structural steel:

Specifications for Structural Steel

Bars and shapes, and plates $1^1/_2$ in. and less in thickness, shall be structural steel conforming to the specifications of ASTM designation A7-49T.

Plates greater than $1^1/_2$ in. in thickness shall be steel made by either or both of the following processes: open hearth or electric furnace. The steel shall conform to the following requirements for chemical composition, as evidenced by the specific ladle and check analysis:

Element	Ladle	Check
Carbon, max. %	0.29	+0.04
Manganese, %	0.60 to 0.90	+0.04
Phosphorus, max. %	0.04	+0.01
Sulfur, max. %	0.05	+0.01
Silicon, %	0.15 to 0.30	+0.03 +0.02

The material, as represented by test specimens, shall conform to the following requirements as to tensile properties:

Tensile strength, psi	55,000 to 65,000
Yield point, min. psi	27,000
Elongation in 8 in., min. %	21

The bending properties, as represented by test specimens, and the number of tests shall conform to the requirements specified for structural steel, ASTM A7-49T.

The grain size shall be 5 to 8 in accordance with ASTM specifications, E19-46.

All structural steel may be flame cut provided a mechanical guide is used and smooth surfaces are obtained. Edge planing will not be required.

All welding shall conform to the requirements of the Standard Specifications for Welded Highway and Railway Bridges of the AWS dated 1947, except as modified herein.

All welding shall be performed either by the submerged-arc process or with low-hydrogen electrodes, with the exception that when welding material less than 1 in. in thickness to other material less than 1 in. in thickness, electrodes conforming to Section 4, article 401 of the AWS specifications, may be used for low-hydrogen electrodes.

Low-hydrogen electrodes shall conform to the requirements of the Military Specifications for Electrodes (mineral covered, low hydrogen), for welding medium-alloy steels, MIL-4-986 (ships) grade 180, dated November 1, 1949.

Special precautions shall be taken when welding in cold weather to avoid undue chilling of weld metal within the zone of welding influence.

The welding technique to be followed in connection with the welding of built-up members of heavy section shall be qualified by test before being admitted for use.

In lieu of provisions of Section 6, subsection 604, article (f) of AWS specifica-

TABLE II. Chemical and Physical Specifications for Plates Only (Ladle Analysis)

Item	Thickness* To $^1/_2$ In.	Over $^1/_2$ In. to 1 In. Incl.	Over 1 In.
Chemical Requirements:			
Carbon, max. %	....	0.25	0.25
Manganese, %	....	0.50-0.90	1.15 max.
Phosphorus, max. %	0.04	0.04	0.04
Sulfur, max. %	0.05	0.05	0.05
Silicon, %	....	....	0.15 to 0.30
Physical Requirements:			
Tensile strength, psi	58,000-75,000	58,000-75,000	58,000-75,000
Yield, psi	32,000	32,000	32,000
Elongation in 8 in., min. %	21	21	21
Elongation in 2 in., min. %	....	23	23

* For material over $^3/_4$ in. to $2^1/_2$ in. inclusive, in thickness, a deduction from the percentage of elongation in 8 in. specified of 0.25 percent shall be made for each increase of $^1/_{32}$ in. of the specified thickness of $^3/_4$ in., to a minimum of 19 percent.

TABLE III. Recommended Welding Procedures for A7 Steel of Various Thicknesses and Carbon Contents*

(Numbered methods are described below)

Carbon Content	Plate Thickness Up to $^1/_2$ In.	$^1/_2$ to 1 In. Incl.	Over 1 to 2 In. Incl.	Over 2 to 4 In. Incl.
Below 0.25% by check analysis	(1)	(1)	(2)	(4) or (5)
Between 0.26 and 0.30%	(1)	(2)	(3)	(5)
Between 0.31 and 0.35%	(2)	(3)	(5)	(6)

(1) No preheat, postheat, or special treatment

(2) 100° preheat and interpass temperature. Stress relief at 1,100° F optional;
or
Exx 15-16 electrodes. No welding below 10°. Stress relief optional.

(3) Exx 15-16 electrodes—no welding below 10°. Stress relief optional;
or
200° preheat and interpass temperature. Stress relief at 1,100° optional.

(4) 200° preheat and interpass temperature. Stress relief at 1,100° optional.

(5) 100° minimum preheat and interpass temperature with Exx 15-16 electrodes. Stress relief optional;
or
300° preheat without Exx 15-16 electrodes. Stress relief optional in both cases. Peening may be required.

(6) 200° preheat and interpass temperature with Exx 15-16 electrodes;
or
300° preheat without Exx 15-16 electrodes both. Stress relief optional. Peening may be required.

* From *Monograph on Weldability*, Welding Research Council (summarized by Sacramento Office of Bureau of Public Roads).

tions, specifying temperatures of contiguous areas to be not less than 130 deg F, when welding members of heavy section, the temperature of contiguous areas about a welding operation shall be substantially equal and not less than 300 deg F.

Furnace stress-relieving of built-up members (girders, caps, and columns), where material over 2 in. in thickness is welded to material of half its thickness or less, as specified under Section 6, subsection 604, article (g) of the AWS specifications, will not be required. Furnace stress-relieving of column bases, where so shown on the plans, will be required.

All welds shall be subjected to non-destructive testing by the engineer. Such non-destructive testing will be performed without cost to the contractor.

Fabrication tolerances for built-up girders and caps shall not be more than 50 percent greater than the American Institute of Steel Construction (AISC) tolerances for WF shapes, and the tolerances for built-up columns shall not be more than 50 percent greater than the AISC tolerances for the WF shapes specified for columns.

After Unit 1 was advertised under these specifications, requiring plates over $1^1/_2$ in. thick to have a yield point of 27,500 psi, such plates were redesigned to reduce the working stress to 15,000 psi. There were fortunately only 200 tons of plates over this thickness out of the total of 4,885 tons in Unit 1.

Study of welding specifications continued after the award of this contract. R. W. Binder, A. M. ASCE, chief engineer of the Bethlehem Pacific Coast Steel Corp. in Los Angeles (which has the subcontract for fabricating the steel for Unit 1), cooperated in the study. Data from the Bureau of Standards and the Battelle Institute were furnished by Eric L. Erickson of the Bureau of Public Roads. As the result of discussions with the Bethlehem Pacific Coast Steel Corp., Mr. Erickson called a conference in Washington, D.C., of the following persons: Jonathan Jones, Hon. M. ASCE, Chief Engineer, Fabricated Steel Construction, and W. Paul Gerhart, Chief Metallurgist, Bethlehem Steel Co.; Earl H. Davidson, Metallurgical Engineer, and Stewart Magee, Representative, U. S. Steel Co.; and Raymond Archibald and Nathan W. Morgan, Members, ASCE, respectively Bridge Consultant and Principal Highway Bridge Engineer, Bureau of Public Roads.

As a result of this conference it was decided that there was objection to specifying fine-grain steel (because of the present difficulty in obtaining aluminum) and steel having less than 0.25 percent carbon by ladle analysis. It was also stated that under present conditions a specification calling for normalizing was impractical. Chemical and physical specifications were proposed for consideration and are given in Table II.

Mr. Erickson recommended consideration of Navy Specification HT steel because of its higher yield point and good weldability. Under existing conditions, however, it was considered inadvisable to specify steel alloyed with restricted metals, in the specifications for the next unit to be contracted. The specifications for the next four units were therefore revised to the chemical and physical requirements given in Table II for plates only and for A7 steel for rolled beams.

A copy of a "Monograph on Weldability" (marked subject to revision), prepared under the auspices of the Welding Research Council, was received for tentative consideration (Table III). It will be noted that the required preheating temperatures are of the same order as the 130 deg F currently specified by the AWS but that these temperatures now vary with the thickness and carbon content. In view of these proposals the requirement for Unit 1 of a minimum preheat temperature of 300 deg F is conservative. On the other hand, some of the information on welding seems to indicate that a minimum temperature of 400 deg F has special significance. Table IV gives chemical, physical, and heat-treatment requirements for plates.

There is apparent agreement that the submerged-arc process and the use of low-hydrogen rods are the best practices known at the present time for welding and should be required. If the proposals are correct, A7 steel of any thickness and carbon content, up to 0.35 percent maximum, can be welded safely with a minimum 200 deg F preheat and interpass temperature. This conclusion seems contrary to opinions expressed by many metallurgists, some of whom have stated that steel with over 0.25 percent carbon is not safe for welding heavy structural members.

Shop Inspection

As stated previously, shop inspection practices for welding have not yet been as well established as those for riveting. For this reason proper shop inspection is one of the most important phases to be considered by the structural engineer if welded construction is to advance as it should.

For this project inspection at the eastern rolling mill is being carried out by a consulting commercial testing laboratory in much the same way as for a riveted job. The A7 steel is subject to normal mill inspection and physical tests. The special steel for plates more than $1^1/_2$ in. thick is subject to chemical check analysis and also to grain-size determination. The grain size is classified by the McQuaid-Ehn test. All testing and inspection of the steel are subject to the general requirements of ASTM specification A6. As is usual in

(*Continued on page 238*)

TABLE IV. Chemical,* Physical, and Heat-Treatment Requirements for Plates

(*Specifications for Units 5 and 6 not yet prepared*)

	Unit 1	Bayshore Freeway†	Unit 2‡	Unit 3	Unit 4
Plate Thickness→	Over $1^1/_2$"	Over 1"	....	Over 1"	Over 1"
Carbon, max. %	0.29	0.25	....	0.25	0.25
Manganese, max. %	0.60 to 0.90	1.15 max.	....	1.15 max.	1.15 max.
Phosphorus, max. %	0.04	0.04	....	0.04	0.04
Sulfur, max. %	0.04	0.05	....	0.05	0.05
Silicon, %	0.15 to 0.30	0.15 to 0.30	....	0.15 to 0.30	0.15 to 0.30
Grain size	5.0 to 8.0	Not specified	....	Not specified	Not specified
Tensile strength	55,000 to 65,000	58,000 to 75,000	....	58,000 to 75,000	58,000 to 75,000
Yield point, min. psi	27,500	32,000	....	32,000	32,000
Elongation in 8 in., min. %	21	21	....	21	21
Elongation in 2 in., min. %	....	23	....	23	23
Brinell hardness of heat-affected zone	190	190	....	190	190
Heat treatment	Over $1^1/_2$" 300° F	Over $1^1/_2$" 300° F	....	Over 2" 100° F	Over 2" 100° F
Working stress, psi	15,000	18,000	....	18,000	18,000

*Chemical composition shown is for ladle analysis.
† One bridge, three-pedestrian outer crossing.
‡ Substructure only; no structural steel.

Sequence and continuity mark

Structural steel fabricators with adequate and competent organizations have always assumed the responsibility for studying the latest developments in connection with design and fabrication of steel structures. Included in their personnel are engineers whose task it is to view each job from the standpoint of sound engineering. As new developments take place, as new methods are proposed and used, these engineers have the obligation of evaluating them. Progress in the fabricating field has been made by carefully analyzing the results and by integrating successful methods into current engineering practice. Just as with other new developments, this procedure has been applied to the introduction of welding into the field of fabrication.

In 1925, at the time the Los Angeles (Calif.) City Hall was fabricated and erected, all major structures were riveted. During the next few years welding was used to perform certain functions in the shop—tack welding during the fit-up of assembly pieces and the welding of nominally stressed details as well as the fabrication of bases, mud tanks, and skids for the oil industry. In 1930, an all-welded steel frame was fabricated and erected for the Southern California Telephone Co. in Whitewater, Calif.

The Kern River Bridge, completed in 1941, was the first highway bridge designed by the California State Highway Bridge Department employing welds to carry calculated stresses. This bridge is 1,342 feet long and is made up of twenty-two 61-ft continuous steel stringers (in approximately 300- to 400-ft lengths), using three lines of 33-in. wide-flange beams with shear connectors for composite action of the 7-in. reinforced-concrete roadway slab. Short-length cover plates, 10 × $^3/_8$ in., were welded with $^3/_8$-in. intermittent welds to the bottom flange of the girders at the supports. Bar stiffeners were welded to top and bottom flanges and to the web with $^3/_8$-in. intermittent welds. The ends of the covers were tapered to a blunt end in a relatively short distance. The shear connector used was a 2- × $^5/_8$-in. bar welded in a vertical position at spacings varying from 6 in. to 1 ft 6 in. Field splices of the wide-flange shapes were made 13 ft from each pier (at points of minimum moment) by butt welds. Because of experience reported from Germany in connection with butt-welded splices for other than rectangular shapes, the California State Highway Bridge Department has made periodic inspections of these joints, and to date such inspection has failed to disclose any visible cracking of welds.

After 1941, numerous simple-span wide-flange stringer-beam bridges were welded. The welded details which were used for these spans have changed but little over the years and are now accepted as a very satisfactory solution for spans of moderate length. For somewhat longer spans, wide-flange beams with bottom cover plates (when necessary), and shear connectors for composite action with the reinforced-concrete roadway slab, have come into more extensive use.

In 1950 an all-welded bridge of battle-deck floor construction with asphalt surfacing was erected across Smoky Gulch near Indio, Calif. The bridge, 28 ft wide and 228 ft long, was made up of 48 prefabricated panels, 7 ft 0 in. by 19 ft 0 in. each, supported on existing timber bents. Each panel was made up of a $^7/_{16}$-in. deck plate, welded to two 10-in. fascia channels and three 10-in. wide-flange stringers. The panels, weighing approximately 2.5 tons, were lifted into place in the field by a truck crane. Adjacent 10-in. fascia channels were bolted together to complete the bridge superstructure, except for hand railing and asphalt surfacing.

Current fabrication on the Division Street Interchange project, in addition to the viaduct, includes spans made up of wide-flange beams and welded plate girders, as well as a very interesting all-welded pedestrian overcrossing.

From the few examples which have been cited it can be seen that the use of welding for highway bridges in recent years has become more common in steel fabrication. It should be noted, however, that rigid-frame construction, with its many complex fatigue problems, is not involved in these jobs. As welding has been progressing, designers and fabricators who have followed its development through experience and the very extensive research on weldability recognize that a number of debatable and unsolved problems still exist.

The fabrication of the all-welded viaduct on the Division Street Interchange in San Francisco is the latest step forward. The particular part of the interchange with which this

R. W. BINDER, A.M. ASCE

Chief Engineer, Fabricated Steel Construction

Bethlehem Pacific Coast Steel Corp., Los Angeles, Calif.

modern welding practice

article deals is the "Ninth and Tenth Street Connection," which is a viaduct with on and off ramps providing immediate access to the completed section of the Bayshore Freeway to the south. The Ninth and Tenth Street Connection is a very complex system of ramps and levels involving skew connections, changing grades (with accompanying vertical curves), and horizontal curves. To appreciate the complexity of the structure, one should note that more than three hundred 24- × 36-in. sheets of detail drawings and calculations were required in excess of the number of design drawings supplied by the State of California.

This viaduct was designed from the start as an all-welded steel structure, other materials or methods having been ruled out because of weight, clearance, and esthetic considerations. Since the structure was designed for welding, it is not the intent of this article to discuss the relative economy of using any other method of fabrication, and therefore no direct comparisons will be made. The design is an intelligent, thoroughly competent, and well thought out plan which considers, in so far as practical, certain requirements imposed by welded fabrication, such as proper selection of material and electrodes, mill and fabrication tolerances, control of distortion and shrinkage stresses, reduction of cooling effects, simplicity of detail and erection.

The interchange superstructure can be considered in two separate parts:

1. The longitudinal deck structure consisting of the concrete deck slab supported by longitudinal steel beams and girders.
2. Transverse steel bents consisting of transverse carrying girders and one or two column legs with a steel grillage base which is incased in concrete.

The longitudinal deck, except for the design considerations previously stated, could have been supported by timber or concrete piers or bents inasmuch as it acts independently as a series of simple spans with one end providing for expansion and the other end being fixed to the supporting bent by welding after the steel dead-load deflection has taken place.

For the utmost economy and suitability, the bent spacing, in so far as practical, was held to under 60 ft to take advantage of rolled beam sections. There are some spans between 60 and 85 ft, and here the wide-flange beams have cover plates welded to the bottom flange. The cover plates are generally about three-quarters of the span length and are continuously welded by the semi-automatic process, Fig. 1(*a*).

The typical spans have 36-in. wide-flange beams, spaced at 8 ft 8 in. center to center, which act with the 7-in. reinforced-concrete deck slab through 4- × 1-in. bars welded to the top flange, Fig. 1(*b*). To assist in lining up the longitudinal stringers during erection, 18-in. channel diaphragms are placed at approximately the third points of the span. The diaphragms are connected to bars (shop welded to the beams) with two bolts at each end to facilitate erection, and are subsequently field welded.

The shear bar connectors and their welding are important design considerations, as the amount of slip which can take place between the concrete slab and the steel beams is dependent on these connectors. In the past, many types of connectors have been fabricated, including channels, angles, tees, and vertical bars. For this project the shear connectors are novel. They are 4- × 1-in. bars with their bottom edge cut to a 1 to 4 bevel and positioned with the bars inclined toward the point of maximum positive moment, in this case the center of the span. The shear connectors are welded to the top flange with $^5/_{16}$-in. continuous fillet welds made by the semi-automatic process. Any negative camber which may result from welding is offset by inspecting the beams before welding and turning them to take advantage of the existing rolled-in camber. The maximum longitudinal spacing of the shear connectors is held to 24 in. The longitudinal shrinkage in the length of beam flange due to the large number of transverse welds, although of minor importance considering that all other details can be accurately welded into position after the shear connectors are welded, was held to a minimum as a result of the welding procedure used. Fortunately, the bars on the top flange do not affect the erection, as no overhead erection equipment is contemplated.

Longitudinal stringers of 91- and 94-ft span are welded girders 42 in. deep, and the 106-ft spans are 48 in. deep. These girders are made up in three sections with the flanges from

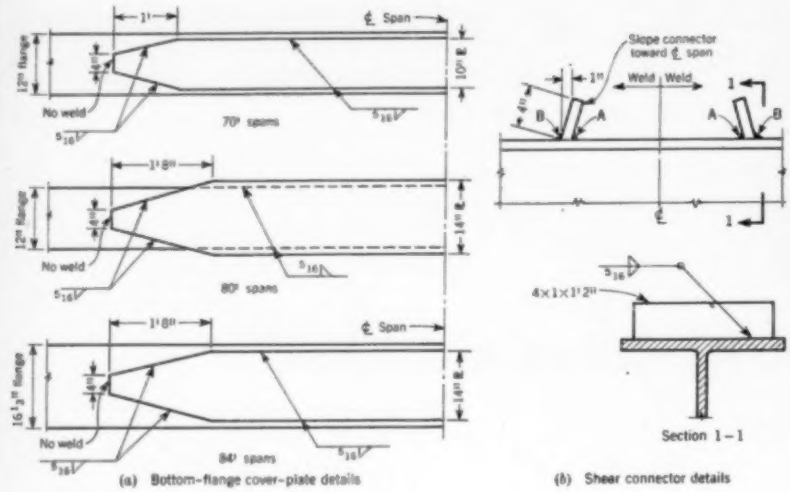


FIG. 1. Cover plates of beams, in (*a*), generally are about three-quarters of beam length, and are continuously welded by semi-automatic process. Shear connectors, in (*b*), shown in photo, have maximum spacing of 24 in. All welding was worked from center toward ends, with welds "A" completed before welds "B" were started.

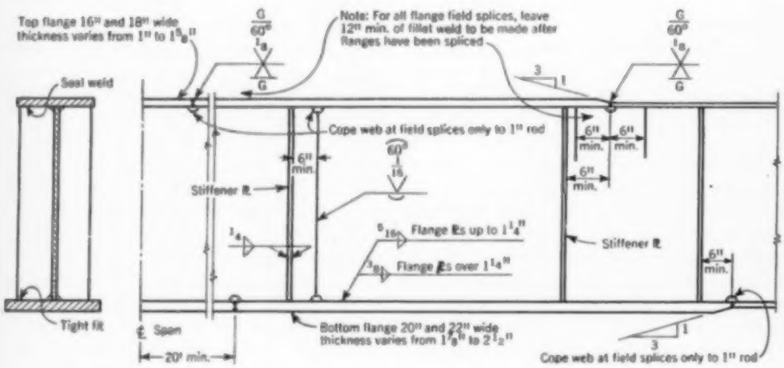
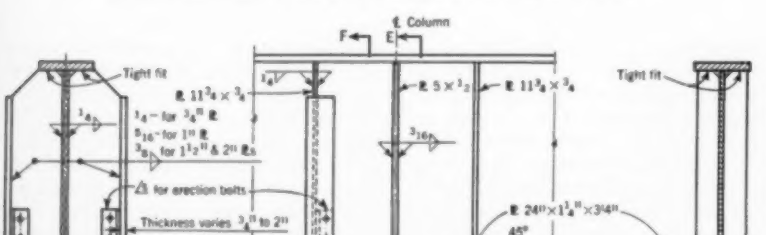


FIG. 2. Longitudinal girders are made up in three sections with flanges from 15 to 22 in. wide and from $^3/_4$ to $2^1/_2$ in. thick.

FIG. 3. Transverse cap girders are similar in makeup to longitudinal girders except that cantilever sections have sloping bottom flanges. Stiffened beam seats take beam reactions on each side of web.



15 to 22 in. wide and from $^3/_4$ to $2^1/_2$ in. thick (Fig. 2).

Shop Welding

The general method of shop fabrication for individual sections is more or less conventional in that flanges and web sections are assembled by tack welds and held in place by fixtures for automatic or semi-automatic welding along the web-flange joints. Stiffeners are fitted to the tension flange (without a weld), then welded to the web with $^1/_4$-in. fillet welds and to the compression flange with an $^1/_8$-in. seal weld.

The welding of three plates to make

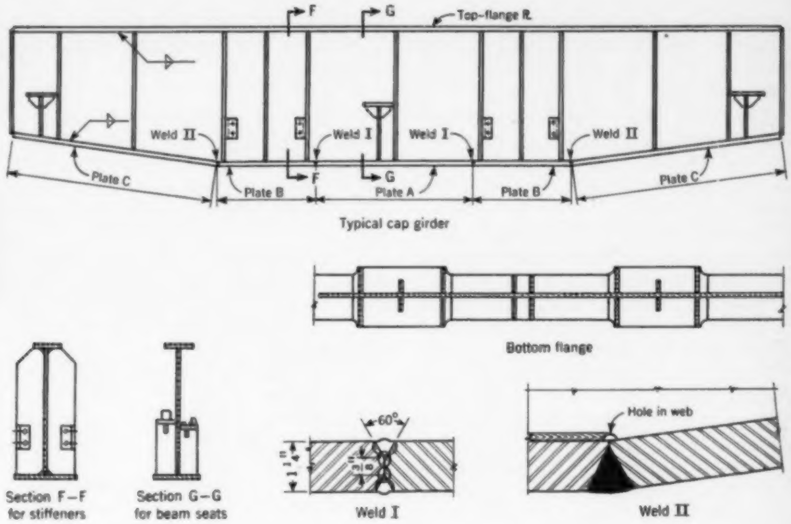
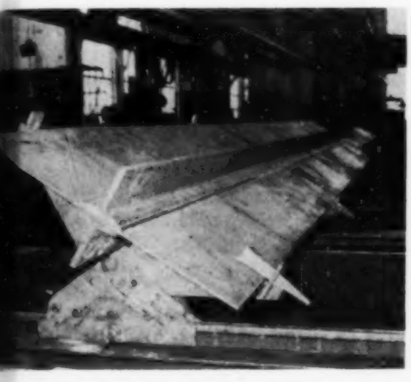


FIG. 4. Shop splices of webs of transverse girders are completed before assembly of girders is started. This permits free expansion and contraction, and helps eliminate residual stresses. Completed cap girder, shown in photo, has stiffened beam seats welded to correct elevations to take beam reactions on each side of web.



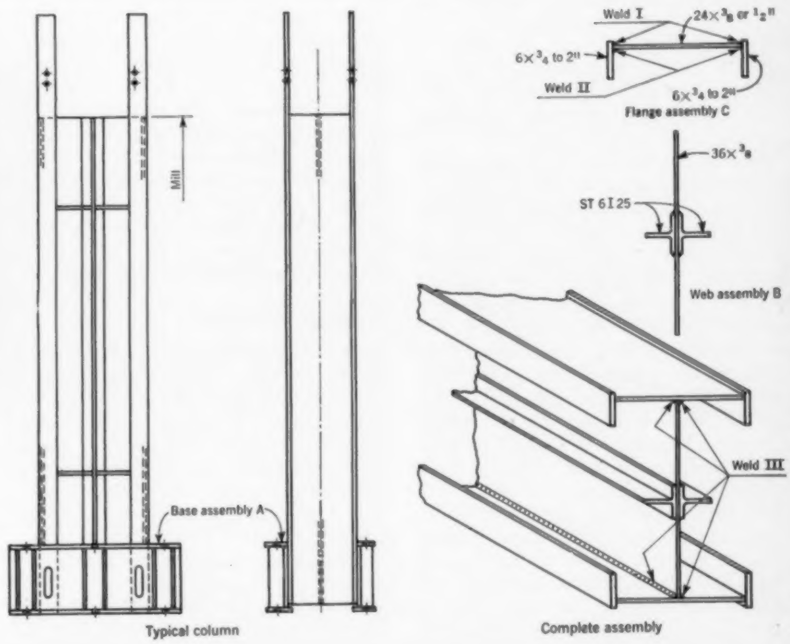
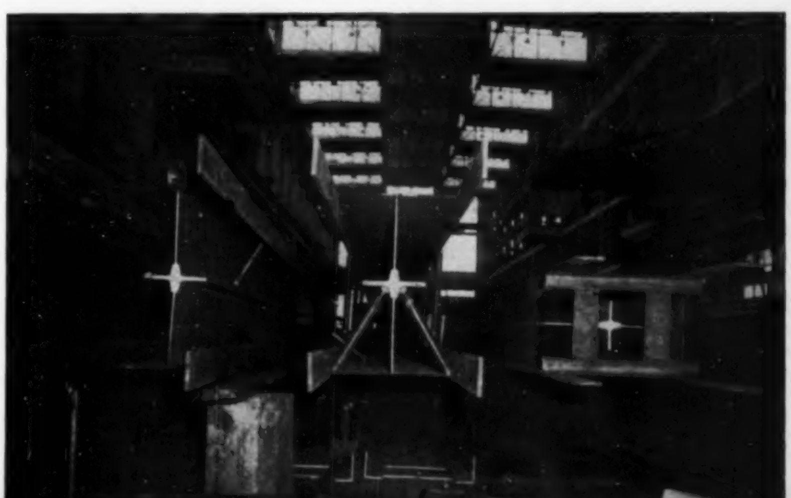


FIG. 5. Each column is built up of five separate subassemblies, two base members, two flange members, and one web piece. Photo shows web assembly in holding device for welding longitudinal split tees.

a girder section furnishes an excellent opportunity to study, for fabrication purposes, the bowing and distortion caused by shrinkage. Longitudinal shrinkage of the web-flange welds contributes to the bowing of the girder. Bottom-flange welds tend to create a positive camber. Top-flange welds give a negative camber. The magnitude of camber and the tendency toward cracking of welds are tied into the heat input and cooling rate, which in part are affected by



Subassemblies "B" and "C" are fitted together, tack welded, and held in fixture of pipe jacks for final welding.

the following nine factors: (1) manual welding versus the submerged-arc process; (2) size of bead; (3) number of beads; (4) preheating; (5) welding sequence; (6) design (which may involve all the foregoing factors); (7) contour of beads; (8) fit-up; and (9) conditioning and type of electrode.

A knowledge of these factors is important to the fabricator who desires to avoid cracking of welds and to hold the section straight in order to avoid special corrective measures in the shop should the section be out of line. Transverse shrinkage of web-to-flange welds contributes to the distortion of the flanges. In the heavier flanges, as on this project, little distortion takes place. However, for thin material, fabricators generally precamber the flanges so that they will come into line during welding. The transverse stiffeners, tack-welded to the web, will act as strongbacks to keep the web from buckling. In many cases the sequence of stiffener welding will be an important factor in helping to keep the section straight or in nullifying previous negative camber.

For ease in handling, the long girders will be made up in three separate sections before final assembly. The main girder splices will be at points where flange plates change in thickness. Because heavy flanges (up to $2^1/_2$ in.) are to be spliced, special treatment is necessary to minimize shrinkage and any tendency to crack. In general, the shrinkage forces will occur because of an improper welding sequence or differences in shrinkage between light web-splice welds and heavy-flange butt welds or a combination of both. A correctly chosen sequence and technique can go a long way toward minimizing such forces. However, in addition, a suitable arrangement should be selected to provide free movement of girders while welding.

Investigations on heavy highway plate-girder splices in Germany have revealed that, where possible, in order to keep "locked-up stresses" to a minimum, flange and web-splice welds should be made simultaneously with welding, beginning in the root of the flange splices and then proceeding to the web splices very soon thereafter. Usually this means employing several welders so that the root layers will not be allowed to cool first, thus resulting in cracking. This procedure helps to prevent web-flange restraint, although warping of flanges may still occur.

With the web vertical, the girder supported, and the splice free of any dead-load moment, two welders may be used to perform the following operations:

1. To fit up the splice, maintaining a minimum root opening of approximately $^1/_8$ in., then to tack weld the web securely.
2. To weld the flanges so that the butt joints are approximately 50 percent complete.
3. To complete the web-plate welds, keeping the welds balanced.
4. To complete the flange welds, at the same time as the web welds, in so far as practicable.
5. To weld the free ends of the webs to the flanges.

Transverse Bents

The transverse steel bents are one-legged or two-legged column bents consisting of built-up plate columns and plate-girder column caps which carry the end reaction of the longitudinal beams. Unusual and striking in appearance, some of these single-column bents rise 60 ft above ground level.

The transverse cap girders (Fig. 3) are similar in makeup to the longitudinal girders except that the cantilever sections have sloping bottom flanges. In addition, these members have stiffened beam seats welded at correct elevations to take the beam reactions on each side of the web.

Sequence of Welds

The cap-girder stiffeners are field welded to the column flange bars which extend upward for the depth of the girder. Two fit-up holes are provided in an angle clip at each bar so that, when the girder is set on top of the column, eight bolts at each column will hold it in place during welding.

The shop welding sequence for these cap girders (Fig. 4) is substantially as follows: The bottom-flange plates are $1^1/_4$-in.-thick material. However, since plates "A" and "B," Fig. 4, have different widths, they must be spliced as shown at weld "I." This weld is made before assembly to the web to permit freedom of movement. The edge preparation used is the result of some experimentation by the shop in search of an efficient joint. Both sides of each plate are beveled to make a 60-deg double vee, leaving a $^3/_8$-in. edge which is just thick enough to prevent burn-through, although permitting complete penetration by the root passes of semi-automatic welders. A 60-deg vee is used so that the semi-automatic tip can get down into the groove far enough for the first pass. The secret of making a successful weld hinges on full penetration and a sound first pass.

The weld is filled in on one side before turning the plate over and completing the other side. This procedure is possible because of the welding speed and penetration afforded by the semi-automatic process.

Welds marked "II," between plates "B" and "C," are handled in a different way because flange plate "A" has previously been welded to the web. The edge at this splice is so prepared that most of the weld can be applied manually in the flat position on one side, using a single V-joint. A semicircular hole is cut out of the web so that the rod can be manipulated through for the back-up pass in order to obtain a sound, continuous butt weld. This hole is often left open because it is felt that any closure by welding may produce a defective notch effect, with considerable restraint, which could be more serious than the open hole.

The flange-to-web fillets are made by two semi-automatic welders working simultaneously on opposite sides of the web, starting at the center of the girder and proceeding together toward the same end for each pass. The beam-seat assemblies built up as separate pieces are fitted to the girder along with other detail and web stiffeners, and are welded last by manual methods.

The makeups of the column sections vary according to requirements but, in general, have a web plate, reinforced with beams or tees, and flange members of considerable width which have flat bars welded along their edges to form a channel-shaped member. These flat bars are extended above the girder seat and are field welded to cap-girder bearing stiffeners, as shown in Fig. 3.

Column Makeup

Five separate subassemblies are used to build up each column, including two base members, two flange members, and one web piece. The welding sequence for a typical built-up column (Fig. 5) is substantially as follows:

1. The base assemblies "A" (made up of two flange bars, a web plate, and numerous stiffeners) are fitted up and manually welded as separate pieces.
2. Web assembly "B," consisting of one relatively wide web plate and two split tees (or in some cases beams reinforced with channels), is fitted and tack welded to make up one subassembly. Four longitudinal welds are made with

automatic submerged-arc welders running full length, tying the split tees to the web. The top of the web is milled to provide a good bearing surface under the column cap girder.

3. The two flange assemblies marked "C," consisting of a wide web plate and two flange bars, are fitted up into a channel-shaped section, tack welded securely, and placed in a holding fixture for welding by automatic machines. Welds marked "I" and "II" are made in that order, turning the piece between the two passes.

4. Subassemblies "B" and "C" are then fitted together, tack welded, and also held in a fixture of pipe jacks for subsequent final welding. Welds "III" are made starting from the top or milled end, using two semi-automatic submerged-arc welders or two manual welders. Stiffeners are placed and welded after welds "III" are complete.

5. Base assembly "A" and structural detail are now added to the column, and the final welds are completed by manual methods.

Welding Standards

Because the Bayshore Viaduct, with which the Division Street Interchange connects, involving approximately 26,000 tons of fabricated structural steel, is probably one of the largest all-welded bridge projects to be constructed, considerable discussion was held by the State of California engineers with leading welding authorities and representatives of steel mills and structural steel fabricators, especially in regard to welding thick material. The basic specifications to be followed are:

1. Standard Specifications, January 1948, of the State of California, Division of Highways.
2. Standard Specifications for Highway Bridges of the American Association of State Highway Officials, 1944.
3. ASTM Specification A7 for material $1^1/_2$ in. thick and under.
4. AWS Standard Specifications for Welded Highway and Railway Bridges, 1947, except as modified by special provisions for this job.

Special conservative provisions for this section of the viaduct, involving 4,800 tons, of which approximately 5 percent is thicker than $1^1/_2$ in., were drafted on the basis of the information obtained from the experts consulted by the State of California. The experts concerned do not contend that these special provisions are all-inclusive or perfect but rather that they do meet with the general approval of the interested parties and as such are tentatively acceptable.

Shop handling of long and relatively limber pieces is often troublesome and slow. Edge preparation must insure proper fit up as well as provide surfaces that are clean, smooth, uniform, and free from fins and other defects so that sound welds of the proper contour can be obtained. This type of careful preparation necessitates the use of large floor areas and considerable time for layout, setting up, machine burning, cleaning, handling, and burning the pieces. Fitting up, of course, is one of the fabricator's major problems and is another important factor in obtaining sound welds. On this project, since standard jigs were of little use, special jigs and fixtures were built to suit the fabricating requirements. To avoid cracking, the fit-up must permit breathing space for the weld during shrinkage.

Tack welding is often employed to hold members in place, and some practical problems are met even here. For example, how large should the tack weld be and how can cracking be prevented or repaired? Fit-up sometimes also means pre-positioning the piece out of line so that cooling and shrinkage stresses will bring it back into relatively correct position. Many and varied expedients are used to minimize wrinkles or warping of thin webs. In addition to operational difficulties, application of the weld presents technical problems and also practical ones, such as cleaning each layer thoroughly. Welding supervisors must be certain that the equipment is in first-class condition and that welders are qualified and generally appreciate the importance of their task. These are but a few of the duties which a fabricator's welding supervisor must assume in order to assure a first-class finished product.

One particular engineering aspect that does not seem to appear very often in welding literature is the problem of the proportions of thin to heavy material. For example, what is the limit of thickness of the 6-in. flange bars on built-up channel flanges of column bents which have constant column webs of 24- × $^3/_8$-in. material? We do not know what this limit is, but we are inclined to believe that the viaduct design approximates the upper limit. The California Highway Department is contemplating taking SR4 strain-gage readings in strategic locations on column bents, and results may give some insight into this subject.

A comparison at this time between the Kern River Bridge and the structure now under discussion might serve to point out the advances in welding made during the past ten years. On the Kern River Bridge, $^5/_8$-in. cover plates were welded with short-length, $^3/_8$-in. intermittent fillet welds. On this viaduct, cover plates as thick as $1^1/_4$ in. are welded with $^1/_4$-in. continuous fillet welds. The continuous fillet welds obviously lend themselves to the use of semi-automatic or automatic welding processes.

Of interest also is a comparison of the relative length of covers with respect to span length, of the end taper of cover plates, and of the welding at the tapered ends of the cover plates. The stiffeners on the Kern River Bridge are welded to the tension and compression beam flanges with $^3/_8$-in. fillet welds, and to the beam webs with short-length $^3/_8$-in intermittent fillet welds, whereas for the viaduct the stiffeners are fitted to the tension flange, seal-welded to the compression flange, and welded to the web with $^3/_{16}$-in. continuous fillet welds (to make the stiffener size comparable to Kern River).

Attention is also called to the change in the type of shear connectors. Of particular interest on the viaduct project is the almost complete use of continuous fillet welds of minimum size, consistent with the maximum thickness of material to which the weld is applied.

Since harmony and a common purpose exist between the State of California inspectors and the fabricator's welding forces, it is believed that the best possible welded job is being produced. All testing for the state is under the direction of J. L. Beaton, Supervising Highway Engineer.

The Division Street Interchange project is under the direction of G. T. McCoy, M. ASCE, State Highway Engineer. Bridge design and construction are under the direction of F. W. Panhorst, Assistant State Highway Engineer; Stewart Mitchell, Principal Bridge Engineer; and I. O. Jahlstrom, Principal Bridge Engineer—all Members of ASCE. Leonard G. Hollister, M. ASCE, was in charge of the design of this project.

For Bethlehem Pacific Coast Steel Corp., steel is being fabricated at the Alameda Works under the direction of I. F. Kurtz, Manager of Works, and R. E. Gauthier, A.M.ASCE, District Engineer. General Contractor is Charles L. Harney, Inc., of San Francisco.

(This article is based on the paper presented by Mr. Binder before the joint session of the Structural Division and the American Institute of Steel Construction, presided over by R. N. Bergendoff, member, Executive Committee of Structural Division, at the Centennial Convention in Chicago.)

ENGINEERING REPORTS:

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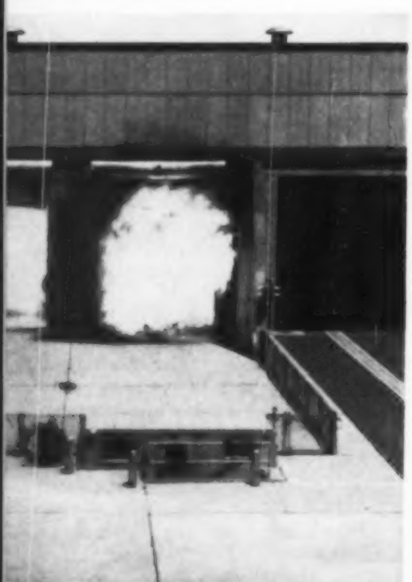
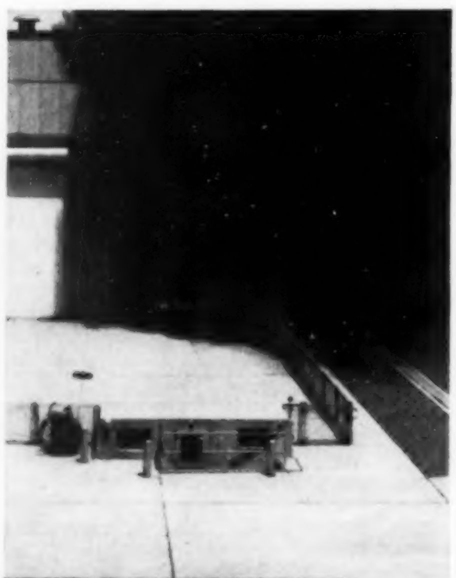
Billion-watt explosions improve



1 FLASH in one of five test cells results from deliberately testing a circuit breaker to destruction. Board at right indicates conditions of the test.



2 SMOKE emerges, while results of the test are automatically measured, recorded on film, and quickly made available for examination by our General Electric development engineers.

3 OBSERVERS emerge from observa tion booth facing test cells t inspect damage. Photos are from shatter proof windows in the control building

SOCIETY NEWS

Welcome to the Centennial Convocation

As this Centennial issue comes off the press, members of ASCE and engineers of other societies from both here and abroad will be in Chicago—part of a vast assemblage of engineers who have come from all over the world to celebrate the one hundredth anniversary of the American Society of Civil Engineers and a century of engineered progress. This is to bid you welcome to a celebration that is the culmination of the hopes and plans of years—a celebration that has set itself the dual purpose of explaining to the public the contributions of engineering to our national growth while providing a technical program of broad professional appeal.

You who are visiting Chicago for the first time will find it the epitome of the past century of engineered progress. During the one hundred years we celebrate it has grown from a pioneer settlement to the second metropolis of the country and the fourth largest city in the world. It was in Chicago that first use was made of structural steel and skyscraper construction had its beginning. And in Chicago today you will have a chance to inspect modern construction miracles, particularly the great superhighway being pushed through the heart of the city.

To increase public awareness of the contributions made by the engineering profession to the living standard of the nation during the century we celebrate, twelve general symposiums have been arranged. For the thousands attending the Convocation for its technical programs, there are the sessions arranged by the ASCE Technical Divisions and the 61 other participating societies. Two other principal features of the Convocation program are new exhibits in the Museum of Science and Industry, which supplement industrial exhibits for which the Museum is already world famous, and the musical extravaganza, "Adam to Atom," which excitingly depicts the search by engineers down through the ages for methods and machines to make man's labors less and his living standards higher. Engineers who enjoy "Adam to Atom" have opportunity to make small contributions ($1 or more) to a Centennial of Engineering Corporation fund to permit school children to attend. These young people form one of the groups to whom "Adam to Atom" is properly addressed.

For the benefit of members who are not able to attend the Convocation, this issue contains thirty major papers being presented in the ASCE Convention part of the Convocation program. Other Centennial papers reviewing other phases of the past century of progress are scheduled for subsequent issues. The October issue will carry a general story and photos of the Convocation.

In behalf of all members, thanks are accorded the many engineering and other professional societies who have cooperated so fully in helping to make the Centennial program of a sister society a success. Similarly, warm thanks are due the hundreds of committee and other members who have labored long and hard for the success of the ASCE Centennial of Engineering.

Special Centennial Events Set for September 6 and 10

Of special interest to members attending the Centennial Convocation will be the events of ASCE Centennial Day, Saturday, September 6, and of Centennial Day, Wednesday, September 10.

Presentation of awards to authors of prize-winning papers in TRANSACTIONS during the past year will take place at a general luncheon on ASCE Centennial Day, as will ceremonies connected with release of the ASCE commemorative stamp. An official of the Post Office Department will speak during the stamp-launching ceremonies. The dinner that evening will feature conferring of honorary membership in ASCE on five engineers and an address by Allen S. Quartermaine, president of the British Institute of Civil Engineers.

Mr. Quartermaine will also speak at the Centennial Day luncheon in connection with the official presentation of scrolls and plaques to ASCE by engineering societies from all over the world. Presentation of the Hoover Medal to C. D. Howe, M. ASCE, Canadian Minister of Trade and Commerce and Defense Production, and of the John Fritz Medal to Benjamin F. Fairless, M. ASCE, president of the U.S. Steel Corp., will be another feature of the Centennial Day luncheon. The huge informal dinner scheduled for that evening at the International Amphitheater will be addressed by ASCE Honorary Member Charles F. Kettering, whose subject will be "A Review of the Century." A special performance of the 1953 Sonja Henie Ice Review will conclude the evening.

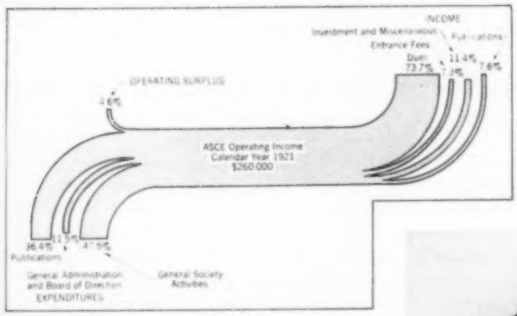
ASCE Convocation Papers Available as Preprints

A number of the ASCE technical papers being presented during the Convocation are available in preprint form. They may be purchased at 25 cents each at the headquarters hotel or ordered from Society headquarters at the same price. Preprints available and a guide to ordering are indicated in the ASCE Convention program.

Congratulatory scroll is presented to ASCE through its president, Carlton S. Proctor, from its sister society, American Society of Mechanical Engineers, by ASME President R. J. S. Piggott. Scroll congratulates civil engineers "on one hundred years of useful life devoted to increase of engineering knowledge and to development and maintenance of high standards of professional practice and ethics. . . ." Scrolls and plaques from foreign societies are being presented at Centennial Day luncheon, on Wednesday, September 10.

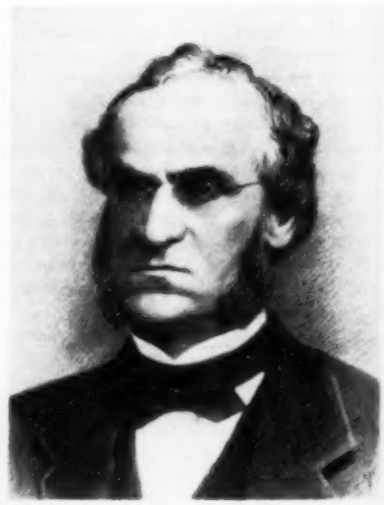
ASCE headquarters for 16 years was in house it owned (upper photo) at 127 East 23rd Street, New York City. Charles Warren Hunt, Secretary 1895–1919, is shown at work in his office.

Persons and Places in

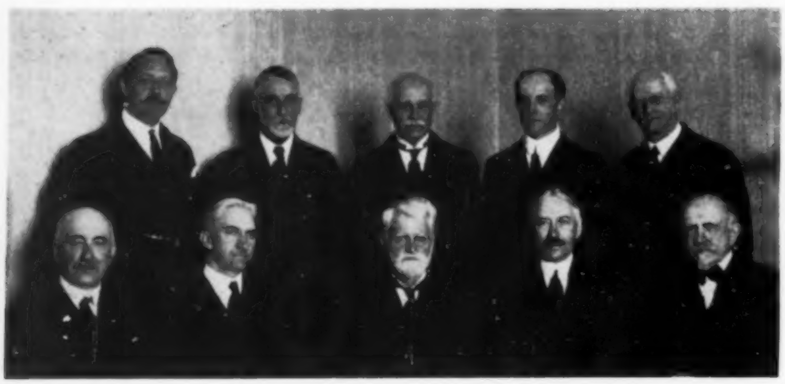


Where and how ASCE dollars served members in 1921 when there were 10,000 members and when the new constitution was adopted which established annual dues at $20.

1884–1894



James Laurie—President 1852



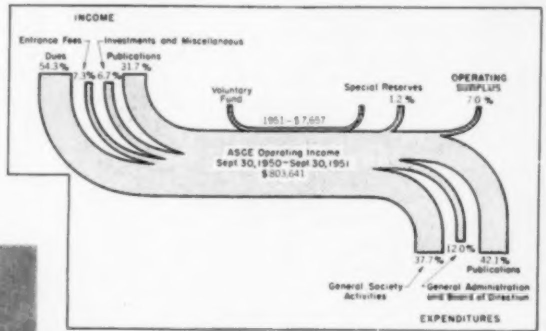
Group of American engineers visiting England in 1921 for attendance at convention of British Institute of Civil Engineers includes many members of ASCE. Seated (left to right) in photo, which was taken in London, are Ira N. Hollis, Arthur S. Dwight, Ambrose Swasey, Charles F. Rand, and John R. Freeman. Standing, in same order, are Robert A. Cummings, Charles T. Main, Jesse M. Smith, F. B. Jewett, and William Kelley.

BOARD OF DIRECTION—1923

1923 Board of Direction is shown at left at ASCE Headquarters in New York in January 1924. Reading clockwise around table, beginning at near end extreme right, are Clifford Holland (d.); George Mason (d.); Walter L. Huber, President designate for 1953; J. J. Yates; Theodore L. Condron; John P. Hogan; F. H. Fenkell (d.); Robert Ridgway (d.); A. N. Talbot (d.); John R. Freeman (d.); George S. Webster (d.); Frank T. Darrow (d.); Anson Marston (d.); R. N. Begien (d.); John N. Chester (d.); Richard L. Humphrey (d.); Frank E. Winsor (d.); Ezra B. Whitman; Arthur J. Dyer; Baxter L. Brown; Carolina Crook (d.) secretary to Secretary; John H. Dunlap (d.) Secretary ASCE; C. F. Loweth (d.) President ASCE; Otis Hovey (d.); George S. Davison (d.); Ira W. McConnell (d.); and Glenn D. Holmes.

in ASCE History

1894 to date



Where and how ASCE dollars served members in 1951 when there were 34,000 members and dues were still $20.

This building at 220 West 57th Street, New York City, served as Society Headquarters from its opening on November 24, 1897, until 1917 when ASCE moved to Engineering Societies Building at 33 West 39th Street, New York. Interior (top) shows Board and committee room in 1897. In 1905 a 25-ft addition was made (at right, in photo above).

Carlton S. Proctor—President 1952

During 1935 Los Angeles Convention group of ASCE members and their ladies visit Paramount studios in Hollywood.

In 1934 recently completed Rockefeller Center, New York City, is opened for inspection by ASCE members attending Annual Meeting. This group of Board members taken on occasion includes (seated, left to right) James G. Sanborn, ASCE Secretary George T. Seabury, Harrison P. Eddy, President of ASCE, E. N. Noyes, W. W. Horner, and Ralph J. Reed. Standing (in same order) are Charles E. Trout, B. A. Etcheverry, T. J. Wilkerson, and E. B. Black.

HISTORICAL HIGHLIGHTS

1852 American Society of Civil Engineers founded
1857 American Institute of Architects founded
1871 American Institute of Mining Engineers founded
1880 American Society of Mechanical Engineers founded
1884 American Institute of Electrical Engineers founded
1887 ASCE membership reaches 1,000
1905 First Local Section (San Francisco) organized
1908 American Institute of Chemical Engineers founded
1909 ASCE membership reaches 5,000
1916 ASCE joins Founder Societies
1920 First Student Chapter (Stanford) organized
1921 ASCE membership reaches 10,000
1922 First Technical Division (Sanitary Engineering) organized
1925 ASCE proposes uniform registration
1930 "Civil Engineering" inaugurated
1938 ASCE membership reaches 15,000
1952 ASCE membership reaches 35,000

Work and Play at Past Society Meetings

Baltimore 1941 Spring Meeting is recalled in left-hand photo, in which Charles Gilman Hyde and Gustav J. Requardt, then Directors, compare libations. Washington, D. C., Meeting (November 1949) is addressed by President Truman (right), first and only President of the United States to speak at an ASCE meeting. Lower left-hand view goes back to Salt Lake City Meeting in July 1938 and shows (left to right) R. C. Gowdy, then Vice-President; R. K. Brown, president of Utah Section: Past-President and Honorary Member Daniel W. Mead; and President Henry Earle Riggs. In lower right photo Past-President Arthur S. Tuttle is seen at party at San Antonio Meeting in April 1937.

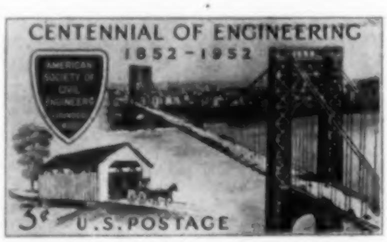
ASCE Stamps to Go on Sale in Chicago, September 6

The three-cent stamp commemorating the one hundredth anniversary of the founding of the American Society of Civil Engineers will be first placed on sale in Chicago on September 6, according to an announcement from the Postmaster General Jesse M. Donaldson. Place and date of sale were selected to coincide with the Centennial of Engineering Convocation in Chicago during the September 3–13 period.

The overall design of the stamp depicts the great advancement made in one phase of civil engineering, that of bridge building. A replica of a typical covered wagon of the 1852 period appears in the lower left-hand corner of the stamp, while dominating the right and central portion is a reproduction of the George Washington Bridge with the New York skyline in the background. Choice of this massive suspension bridge for the stamp is particularly fitting because the first President for whom it is named was a civil engineer.

Dimensions of the stamp are 0.84 by 1.44 in., arranged horizontally, printed by rotary process, electric-eye perforated and issued in sheets of 50. The color of the stamp will be blue. An initial printing order of 110,000,000 stamps has been authorized.

A special post office will be set up in the Conrad Hilton Hotel for the convenience of stamp collectors attending the Convocation. E. Milnor Peck, Head of the Fleetwood Cover Service, Pleasantville, N.Y., is handling first-day covers for the convenience of those not wishing to be bothered by details.



Facsimile of ASCE commemorative stamp

Veteran Society Members Listed

The Society has 21 members of 60-year or longer affiliation. Dean of the group in length of membership is Edward Flad, former Director, who boasts a membership of 67 years going back to 1885. Mr. Flad was second in the last compilation of veteran members (published in the July 1947 issue of Civil Engineering), which listed 30 living members who had joined ASCE in 1890 or earlier. H. S. Jacoby, Hon. M. ASCE, who was 29th on the 1947 list, is tenth on the present revised roll. The present list of 21 members goes back exactly 60 years to September 6, 1892.

These veteran members, with the dates

(*Continued on page 214*)

1918

1952

Latest Permutit Precipitator Saves Up to 40% in Chemicals

Today's sludge blanket Precipitator is the most advanced and efficient type of coagulation, precipitation and settling equipment. It is particularly economical for the removal of turbidity, color, taste and odor; and for softening water, reducing alkalinity and removing silica by the cold lime-soda process.

The secret of its amazing efficiency and adaptability is the full utilization of the suspended sludge-blanket principle. Upward filtration through a blanket of previously formed precipitates results in the complete usage of lime and other chemicals . . . *saving up to 40%.*

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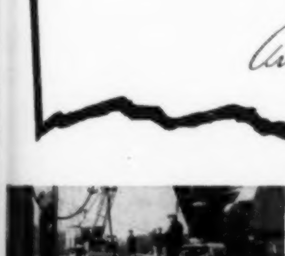
Let us quote you on our low-cost piling rentals—prompt service from five Foster warehouses. Send for Free Piling Brochure illustrating diagrams of all standard-make sections, ask for Bulletin CV-9.



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Piling holds back mud for The Sanitary Trunk Sewer conduit which ran 7 miles on Long Island's South Shore.

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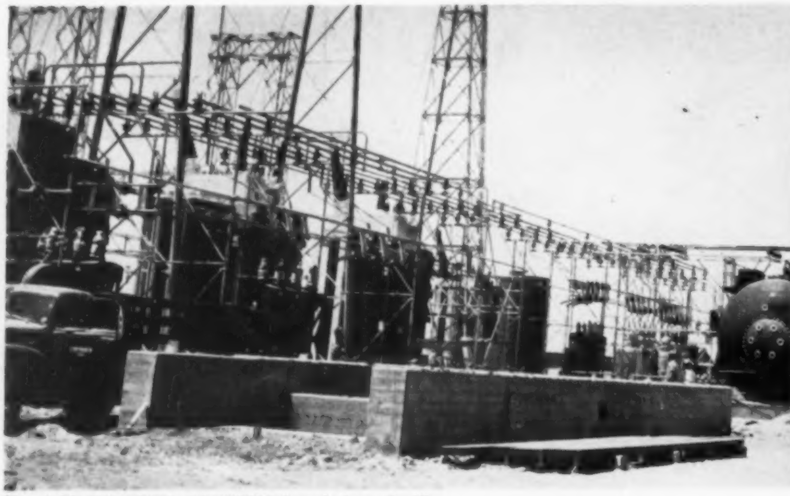

(Top left) **HYDROPEL CONCRETE foundations, Pacific Gas & Electric Company—Midway Steam Plant.**

(Top right) **PLAIN CONCRETE in same location—showing effect of alkali soils.**

PRODUCT	% CAPILLARY ABSORPTION*
ADDITIVE A	8.93
ADDITIVE B	10.60
ADDITIVE C	8.05
ADDITIVE D	8.75
ADDITIVE E	10.19
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ADDITIVE H	10.23
PLAIN CONCRETE (5½ sack)	8.10
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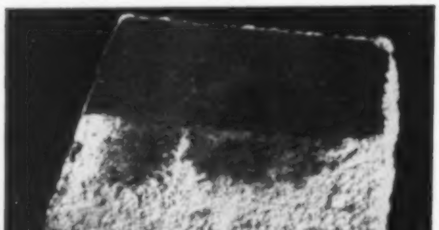
HYDROPEL (5½ sack)	**1.09**

2" x 4" Cylinder of minus 3/8" material, specimens dry at 140° F.

TEST RESULTS as tabulated by Pittsburgh Testing Laboratory show comparative capillary water absorption after seven days.



HYDROPEL BLOCK *(top half)* absorbed little of the salt solution in which it was placed till all had evaporated. Air-entrained concrete *(lower half)* sucked up the solution, leaving destructive salt crystals throughout.

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- Gives the experiences of leading bridge engineering firms who have used the equipment.
- Details Flex-Plane's design, engineering, and service facilities available to the engineers and constructors at no obligation.

Here's a brochure that will come in handy when you're designing a bridge or elevated highway. It fully explains the famed Flex-Plane Bridge and Elevated Highway Concrete Finishing System. Gives you the last word on the latest equipment designed and produced by the nation's largest organization devoted exclusively to machines for the construction of concrete highway and airport systems.

Reserve your copy now! Fill out the handy coupon below, or simply write to THE FLEXIBLE ROAD JOINT MACHINE COMPANY, WARREN, OHIO, and ask for a copy. There's no obligation.

THE FLEXIBLE ROAD JOINT MACHINE CO., WARREN, OHIO

I would like a copy of "Flex-Plane Bridge and Elevated Highway Concrete Finishing Machines."

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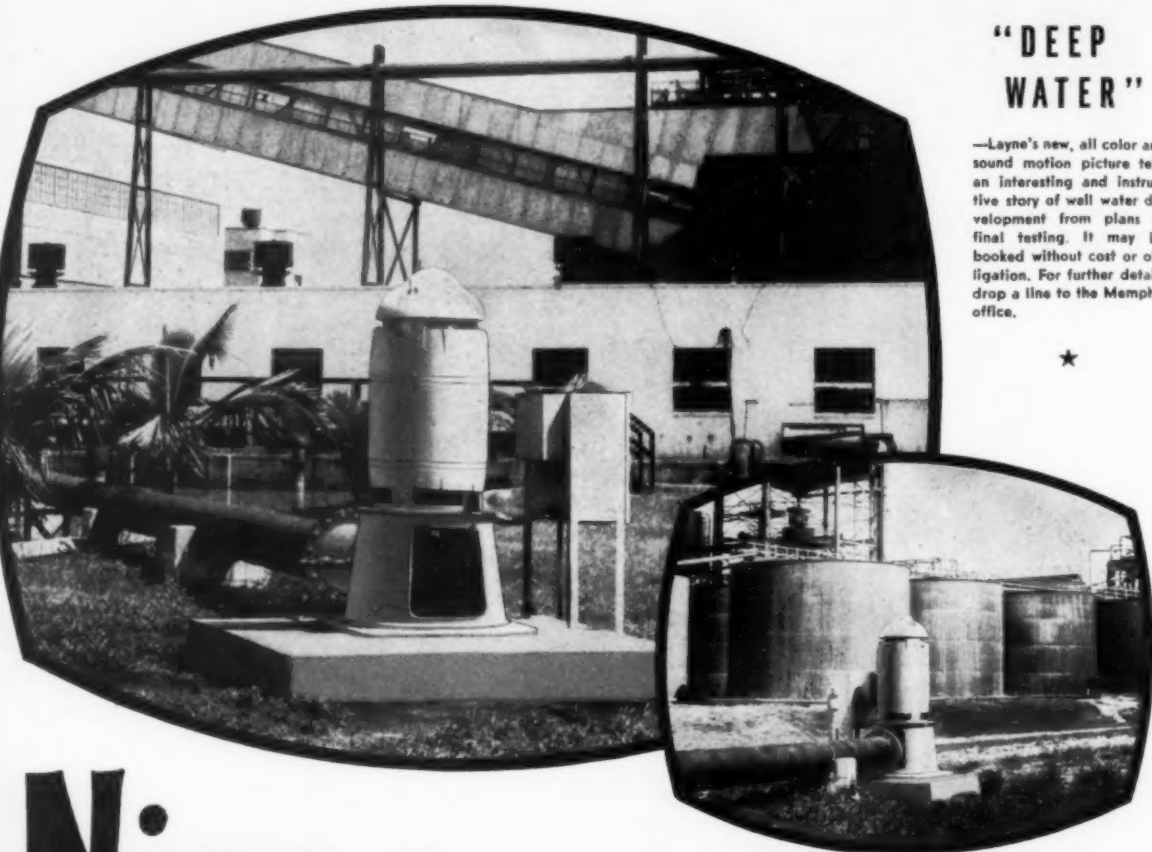
THE HELTZEL STEEL FORM AND IRON CO. — Heltzel BUILDS IT BETTER — WARREN, OHIO

THE FLEXIBLE ROAD JOINT MACHINE COMPANY — Flex-Plane — MECHANIZED CONSTRUCTION EQUIPMENT — WARREN, OHIO



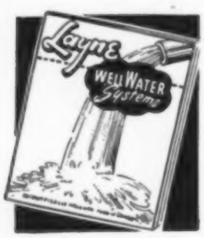
"DEEP WATER"

—Layne's new, all color and sound motion picture tells an interesting and instructive story of well water development from plans to final testing. It may be booked without cost or obligation. For further details drop a line to the Memphis office.

★

Nine Layne Wells

for this big Phosphate mining operator



If you are contemplating the installation of water wells or pumps, it will be worth your while to have copies of our water supply or pump catalogs. Write for copies. No obligation.

Phosphate mining presents many unusual problems, one of which necessitates an ever dependable supply of low cost water. International Minerals & Chemical Corporation, on their big phosphate mining operations near Bartow and Orlando, Florida, are now using nine complete Layne well and pump units. These installations have a total maximum capacity of nearly thirty-thousand gallons of water per minute—enough for greatly increased mining activity.

And so here again we have a case of where water supply failure would stop everything—and where the owner had to be sure that he was buying the utmost in proven dependability, low cost operation and the kind of quality that would assure long life.

But the decision was easy. Layne water supply wells and pumps have an unmatched record of making good on every job no matter how heavy the production, or how long the hours may be. Whether for a mining operation, a city, factory or irrigation farm, Layne wells and pumps always give complete satisfaction and cost less in the long run.

Layne
WATER WELLS
VERTICAL TURBINE PUMPS
WATER TREATMENT

LAYNE & BOWLER, INC.
General Offices, MEMPHIS 8, TENNESSEE

A low-cost Texaco surface for a Black Hills highway

Texaco Slow-curing Asphaltic Oil and aggregate were mixed by travel plant in surfacing of this 10-mile section of South Dakota's Route 24 in the Black Hills area. Work done by the Northwestern Engineering Company, Rapid City, S.D.

The South Dakota Highway Department needed an intermediate-type of construction for 10 miles of State Route 24 in the Black Hills region. A travel plant and Texaco liquid asphaltic materials teamed up to give the State what it wanted—a serviceable, all-weather road at moderate cost.

A dense-graded aggregate was picked up by the travel plant from a windrow and mixed thoroughly with a Texaco Slow-curing Asphaltic Oil. The mix was spread evenly over the base and compacted, providing a tough, waterproof surface two inches thick. Texaco Rapid-curing Cutback Asphalts were used to prime the base and to seal the new surface.

This South Dakota project is another example of the variety of ways in which Texaco Asphalt Cements, Cutback Asphalts and Slow-curing Asphaltic Oils are successfully employed in the construction of roads, streets and airports. There are two reasons why your Texaco Asphalt pavement will stand up under whatever traffic and climatic conditions it is called upon to serve: (1) The experience of almost half-a-century goes into the refining of Texaco Asphalt products; (2) Every Texaco Asphalt material is a product of scientifically selected crudes.

Faithfully yours 50 for Fifty Years

Two helpful booklets covering all types of Asphalt road and street construction can be had without cost or obligation by writing our nearest office.

THE TEXAS COMPANY, Asphalt Sales Dept., 135 E. 42nd Street, New York City 17

Boston 16 • Chicago 4 • Denver 1 • Houston 1 • Jacksonville 2 • Minneapolis 3 • Philadelphia 2 • Richmond 19

TEXACO ASPHALT

Puerto Rico builds homes at rate faster than continental United States. This airview of Puerto Nuevo housing development shows a community of more than 30,000 created in less than four years. It is said to be one of largest private housing projects in world.

Inter-American Convention Previewed

MEETING SCHEDULED FOR SAN JUAN, PUERTO RICO, NOVEMBER 12–15

Puerto Rico will be the setting for the Inter-American Convention, scheduled under sponsorship of the Puerto Rico Section for November 12–15 as part of the ASCE Centennial of Engineering celebration. San Juan, the capital city where the convention is to be held, is served by several large airlines, with daily flights to and from New York, Miami, Chicago, Buenos Aires, Rio de Janeiro, and other large cities, and is a principal port-of-call for most steamships lines entering Caribbean waters. Transportation within the island is convenient and modern.

The Condado Beach Hotel, selected as convention headquarters, is prepared to accommodate a large number of delegates, and the new and ultra-modern Caribe Hilton and other first-class hotels are also available. Rates for rooms during the convention will be \$7 and \$7.50 a day for single rooms and \$9 and \$10 for double rooms and suites. Prices are on the European plan basis. Information on hotels and reservations can be obtained from the Convention Hotel Committee, P.O. Box 2297, San Juan, Puerto Rico.

An Inter-American Program is being prepared by the Program Committee, with emphasis on participation by engineers from South and Central America as well as from all parts of the United States and from Puerto Rico and her sister islands. With delegates expected from practically every nation in the Americas, it is believed that the convention will prove a meeting place for the engineering minds of the continent.

The inaugural meeting is scheduled for the morning of Wednesday, November 12. Technical sessions will be held Wednesday afternoon, Thursday morning, Thursday afternoon, and Friday morning. Several sessions of the ASCE Technical Divisions will run concurrently during some of these periods. The Technical Divisions that will probably be represented with one or more sessions each are the Construction, City Planning, Highway, Air Transport, Soil Mechanics and Foundations, Structural, Power, Sanitary Engineering, and Engineering Mechanics. Members of the Student Chapter at the University of Puerto Rico will conduct one or more sessions open to visiting students and delegates on Friday, November 14.

Special activities planned for the ladies include a social call on the First Lady of Puerto Rico, Dona Ines Munoz Marin, at Fortaleza. For both the engineers and their lady guests the high spot in the non-technical part of the program will be a two-day tour through the beautiful interior and coastal range of the island. This tour, planned for Saturday and Sunday, will show visitors the reason why Puerto Rico is called the Island of Enchantment. An over-night stopover in modern hotels on the south coast with a visit on Sunday to the College of Agriculture on the west coast will give visitors an opportunity to become really acquainted with the island.

The complete convention program will be published in the October issue of Civil Engineering.

Society News

(*Continued from page 198*)

of their first affiliation with the Society, follow:

Flad, Edward '85
Carroll, Eugene '88
Tibbals, George A. '88
Tibbals, S. G. '88
McCulloh, Walter '88
Pierson, George S. '89
Miller, Spencer '89
Moses, John C. '90
Cummings, R. A. '90
Jacoby, H. S. '90
Jordon, William Frederick '91
Walker, Clement Isaac '91
Burr, Edward '91
Guppy, Benjamin Wilder '91
Abbot, Frederick William '91
Sherman, Charles Winslow '91
Baum, George '92
Comstock, Charles Worthington '92
Verenance, William Burnet '92
Wing, Frederick Kelly '92
Sjostrom, Ivar Ludwig '92

Manual on Job Evaluation and Salary Surveys Issued

To help engineers, and more particularly civil engineers, understand the principles of job evaluation, the construction of salary schedules, and procedures involved in making a salary survey, the ASCE Committee on Salaries has prepared a new Manual (No. 30) on Job Evaluation and Salary Surveys. Originally intended as a revision of Manual No. 24 on Surveys of Highway Engineering Positions and Salaries, which was published in 1941, Manual No. 30 has been expanded to include all material essential to the handling of salary problems.

One of the three sections comprising Manual No. 30 describes six separately recognized methods of evaluating positions (jobs); another discusses the construction of salary schedules; and the third describes in great detail a method of making a salary survey. There are 16 exhibits, including a three-page selected bibliography. The 79-page, 6 x 9 publication sells for \$2, with half price available to members of the Society. Copies are obtainable from the Executive Secretary of ASCE, 33 West 39th Street, New York 18, N.Y.

Scheduled ASCE Conventions

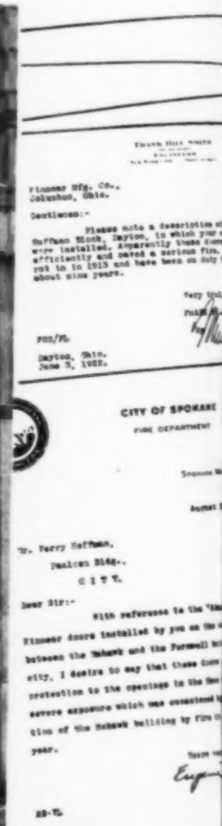
SAN FRANCISCO CONVENTION
San Francisco, Calif., March 2–7, 1953

MIAMI BEACH CONVENTION
Casa Blanca Hotel
June 17–19, 1953

NEW YORK CONVENTION
Hotel Statler
October 19–23
1953

(*More Society News on page 218*)

KINNEAR Rolling Door thr



Even in the days when horse-drawn street cars were trying to hold out against the new-fangled "trolleys", Kinnear Rolling Doors were a favorite of long standing.

n the newest examples f modern, functional uilding design like Cincinnati's famous new errace Plaza Hotel, innear Rolling Doors re widely preferred for fficiency, protection and eauty.

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FROM THE NATION'S CAPITAL

JOSEPH H. EHLERS, M. ASCE

Field Representative ASCE

This month we will review and evaluate several 1952 developments of interest to engineers as seen from Washington.

Legislation in 1952

The outstanding legislative development specifically relating to engineers was the passage of the Defense Production Act Amendment of 1952 exempting from salary controls all "professional engineers employed in a professional capacity." The immediate importance of this is, of course, that it may permit necessary and long overdue adjustments in salaries of some engineers. But for the long pull another aspect is of equal or greater importance. This new development is recognized as an important gain for the profession in respect to legislative recognition wherein engineers are listed alongside lawyers and doctors as entitled to full professional status. Interpretation No. 12 of the Salary Stabilization Board recognizes a professional engineer as of full professional status in definitions useful for indicating that status in other laws and regulations.

Senator Flanders remarked on the floor of the Senate, "The professional engineer does not simply perform a routine duty, no matter how well it must be done. He is a creative person, and we cannot apply salary controls to such a man."

Even the vice-chairman of the Salary Stabilization Board in a speech opposing the exemption said, "The amendment which endeavors to exclude from stabilization all engineers on the grounds that they are professional people like lawyers and doctors, on the face seemed to present a reasonable argument. But unfortunately engineers constitute the most critical manpower shortage with which the defense effort is faced today."

All of this should be good ammunition when we are again called on to battle for complete professional recognition in other legislation and in executive department regulations.

An Armed Forces Reserve Act (P.L. 476) was passed, dealing with the subject in rather general terms. It failed to include certain provisions for the protection of engineers which had been suggested by Engineers Joint Council. Further consideration should be given to this matter in the next Congress to insure that engineering talent will be directed to the most productive uses.

In the rush for adjournment several bills of interest to the profession failed of final passage.

The bill designed to correct the situation resulting from the decision in the "Wunderlich" case, which was passed by the Senate, failed to be brought to a vote in the House because of the hasty adjournment. The Associated General Contractors took vigorous action in respect to this measure. ASCE and AIA also assisted. There would appear to be a good chance of enacting this legislation early in the next Congress, as legislators generally viewed it as equitable and meritorious. It relates to the "disputes clause" in government contracts which gives the contracting officer arbitrary powers in deciding disputes. It is of importance both to contractors and to engineers.

The economic status of the engineer could be aided by one of several bills considered in the 82nd Congress. Engineers Joint Council presented testimony on the Individual Retirement Act, H.R. 4371. An allied bill would permit deduction from income-tax base of sums used to purchase certain government bonds. It will not be easy to secure passage of such legislation. Joint consideration with the architectural, legal and medical societies is essential. These bills failed to emerge from committee in the 82nd Congress. Another possible development being discussed by an EJC committee involves a proposal that self-employed professional persons be made eligible under social security laws.

The next Congress will undoubtedly consider national water policy. The Bureau of the Budget has worked out proposals for submission to Congress. EJC will be relied on to continue its assistance to Congressional committees in formulating legislation.

ASCE MEMBERSHIP AS OF AUGUST 8, 1952

Members	8,213
Associate Members	10,406
Junior Members	16,386
Affiliates	68
Honorary Members	37
Total	35,110
(August 8, 1951	32,739)

Construction Controls in 1952

Each month of this year has seen important changes in DPA and NPA controls on construction. Although the total construction for 1952 will be of record proportions when we include military installations, some types of construction were badly handicapped by materials shortages and controls. Early in the year the lookout was dark. The situation with respect to supplies of the three basic critical metals has now improved so greatly that we may reasonably hope our troubles are nearly over.

Steel-making facilities are now capable of greatly expanded production and, except for specialties such as nickel-bearing stainless steel, will cease to be a deterrent to construction.

Copper and aluminum are no longer considered limiting factors in construction as they have been in the past. The increased availability of foreign copper made possible by price adjustments and the increased facilities for producing aluminum have eased the situation in respect to these two critical metals.

As the shackles fall from the industry, we may look for splendid advances in highway, bridge, public works and building construction.

Inter-Society Activities in 1952

Certain important inter-society activities come within the purview of the Washington office from time to time, particularly relations with organizations that make Washington their headquarters. An outstanding and appropriate feature of the Centennial year was the organization, and exceptionally successful initial meeting, of the Joint Cooperative Committee of ASCE and AIA. It has been obvious for some time that the similar interests of these two professional groups in legislative and executive department matters, as well as in purely technical work, required closer liaison. The Joint Committee has proposed some comprehensive coordinating measures commencing in the universities with Student Chapter activities and possible joint thesis work. Arrangements are being made for an exchange of views in respect to proposed legislation and other activities.

A splendid manifestation of this feeling of unity was the featuring of a special ceremony and exhibit designated "The Re-Union of Engineering and Architecture" at the recent convention of AIA. This was along the lines of activity which the Joint Committee is encouraging. It was particularly designed to mark the one hundredth anniversary of ASCE.

Washington, D.C.
August 5, 1952

WESTERN'S CAISSON PILES

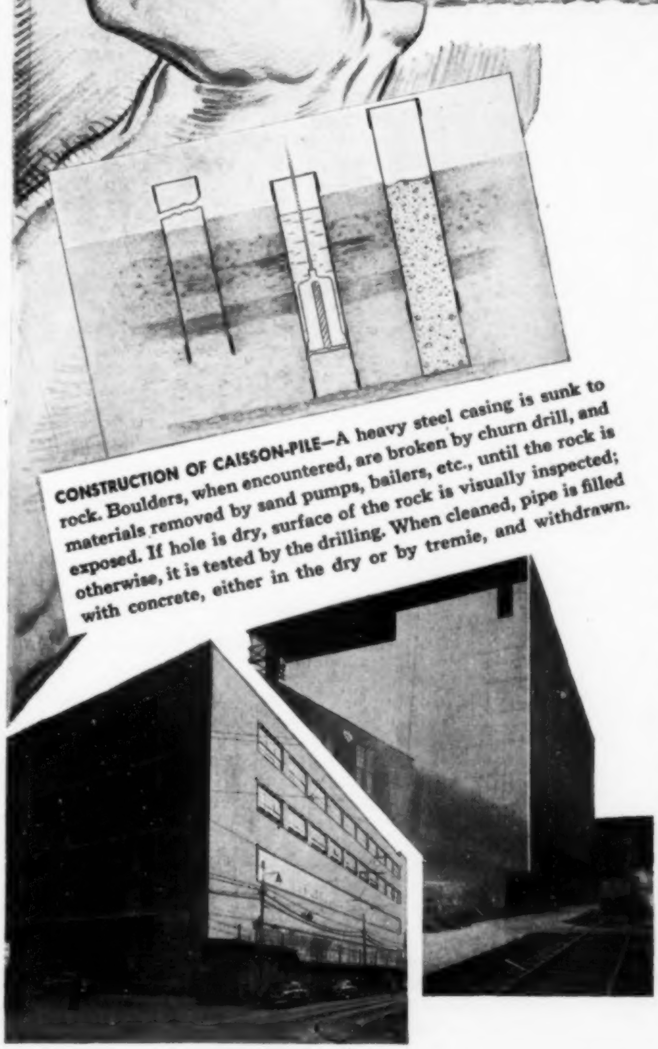
IN ADDITION TO THE STEEL SHORTAGE, unusually difficult soil conditions created a problem in constructing the pile foundations for the Warehouse and D Annex Buildings of the Westinghouse Electric Corp. plant in East Pittsburgh.

THE CLAY WHICH EXTENDS from below the fill to just above the rock is interspersed with layers of soft shale; and a water-bearing sand-gravel layer directly overlying the rock made standard types of open caissons impossible. WESTERN, in cooperation with Stone & Webster engineers, solved the problem and saved a large amount of steel by using WESTERN's all-concrete caisson-piles.

THE CAISSON-PILES were designed for capacities up to 450 tons each. WESTERN installed 191 concrete caisson-piles to complete the first section of this job. Upon completion of the superstructure, WESTERN will install foundations for the second section of the Annex Building. Since the piles rest on the shale bedrock, any possibility of future settlement is eliminated.

DO YOU HAVE A FOUNDATION PROBLEM? WESTERN will be glad to place at your disposal the advice of competent engineers who have handled every type of foundation problem successfully for many years. Ask for brochure illustrating and describing WESTERN piles and services.

COMPLETE FOUNDATIONS FOR EVERY TYPE OF HEAVY CONSTRUCTION. SPECIALISTS IN SHEETPILE AND COFFERDAM WORK.



CONSTRUCTION OF CAISSON-PILE—A heavy steel casing is sunk to rock. Boulders, when encountered, are broken by churn drill, and materials removed by sand pumps, bailers, etc., until the rock is exposed. If hole is dry, surface of the rock is visually inspected; otherwise, it is tested by the drilling. When cleaned, pipe is filled with concrete, either in the dry or by tremie, and withdrawn.

D Annex and Warehouse Buildings of the Westinghouse Electric Corp. plant in East Pittsburgh.

WESTERN FOUNDATION CORPORATION

308 W. Washington St., Chicago 6, Ill. • *2 Park Avenue, New York 16, N. Y.*

NEWS BRIEFS . . .

Northwestern Engineers Celebrate ASCE Centennial

Word of a West Coast celebration of the Centennial of Engineering comes from Portland, Oreg., where on August 9, thirty engineering societies participated in a Northwest Engineering Centennial. A joint proclamation of the governors of Idaho, Oregon, and Washington urged participation in the celebration for its commemoration of the "one hundredth anniversary of the founding of the first national society of engineers in the United States—the American Society of Civil Engineers," and because it "generally marks one hundred years of unprecedented industrial regional growth of the Pacific Northwest."

The all-day program included a review of engineering progress in the Pacific Northwest and a symposium on the future of the engineer and his responsibility to society, with talks by Stanley A. Easton, president of the Bunker Hill and Sullivan Mining Co.; Col. T. H. Lipscomb, E. C. Sammons, and Dr. Tully C. Knoles.

A highlight of the program was the presentation of an award to Herbert Hoover, Hon. M. ASCE, who was cited "the engineer-citizen of the past century." In the major address of the evening dinner meeting, the former President urged the country to stimulate scientific experiment as a means of cutting down inflation. Terming the present shortage of engineers "a great national problem," Mr. Hoover said, "We do not have enough engineers in incubation to carry on the nation's work. We need 60,000 new technologists a year to supply national needs. Our engineering graduates have dropped from 50,000 in 1950 to 38,000 in 1951, and the students in training indicate less than 30,000 next year."

He said that one reason for the drop is the fact that a young mechanic with three years of training, during which he is paid, can earn more than a young engineer with six years of training and three years more of experience. He recommended that the industries themselves consider their responsibility to aid promising boys upon whom the "future existence of industry depends."

The Northwest Engineering Centennial was sponsored by the Professional Engineers of Oregon, with the cooperation of the Professional Engineers of Idaho and Washington.

Chesapeake Bay Bridge is Opened to Traffic

The $45,000,000 Chesapeake Bay Bridge, the first to link the Del-Mar-Va peninsula with the Maryland mainland, was formally opened to traffic on July 30. In addition to connecting the two parts of the state, the project forms a vital link in a north-south route that bypasses Philadelphia, Baltimore, and Washington.

Over three and a half years in the building, the bridge spans the Bay narrow from Sandy Point to Kent Island near Stevensville, connecting with U. S. Route 50 at each end. It consists of four different kinds of spans—through cantilever, two deck cantilevers, suspension, and truss. With an overall length of 7.73 miles, including the approaches, the 28-ft-wide, two-lane project is exceeded in length by only two other overwater structures—the San Francisco-Oakland Bay Bridge and the James River Bridge at Newport News. Cost of the bridge will be financed by tolls, ranging from $1.40 for a passenger car and driver, plus 25 cents for each passenger, to $5 for heavy trucks. These rates are similar to charges for the ferry crossing, which will be discontinued.

The project, which was described in the May 1951 issue of CIVIL ENGINEERING, was built by the Maryland State Roads Commission. The J. E. Greiner Co., of Baltimore, designed and supervised construction of the project, and fabrication and erection of the steel were handled by the Bethlehem Steel Co.

Governors of Delaware and Maryland lead dedication procession over new $45,000,000 Chesapeake Bay Bridge, first to link Maryland's Eastern Shore with the mainland. Tower of 1,600-ft suspension span rises in background. Four different kinds of spans are utilized in project, which has overall length of 7.73 miles.

New Funds to Advance Missouri Flood Control

A long step toward completing major flood-protection projects of the Corps of Engineers aimed at preventing recurrence of disastrous Missouri River floods will be taken in the coming year with appropriations passed by Congress and just signed by the President. In an analysis of project appropriations totaling $90,827,000 for the fiscal year beginning July 1, 1952, Brig. Gen. D. G. Shingler, Missouri River division engineer, said the new funds will enable the Corps to carry Garrison Dam in North Dakota to 62 percent of completion by next July, and Fort Randall Dam in South Dakota to about 77 percent of completion. Substantial progress will be made on Gavins Point Dam near Yankton, S. Dak., for which ground was broken this spring, with an appropriation of $7,750,000. Continued progress on a smaller scale will be possible at Oahe Reservoir near Pierre, S. Dak., for which $3,000,000 was appropriated.

Funds totaling $5,000,000 provide for initiation of construction on the Tuttle Creek Dam in Kansas. The only other new work for which the Corps received construction funds was a local flood protection project at Havre, Mont., for which an initial appropriation of $350,000 was made.

AEC Contracts to Expand Oak Ridge, Paducah Plants

Award of construction contracts for expansion of the Atomic Energy Commission's gaseous diffusion plants at Oak Ridge, Tenn., and Paducah, Ky., is announced by M. W. Boyer, AEC general manager. A $464,000,000 addition at Oak Ridge will be built by the Maxon Construction Co., of Dayton, Ohio. At Paducah, the prime contract on a $459,000,000 addition to the uranium-235 separation plant now under construction has been awarded to F. H. McGraw & Co., of Hartford, Conn. According to Mr. Boyer, a substantial part of the work at both sites will be performed under fixed-price subcontracts.

Architect-engineer firms already at work planning and designing the new facilities include Giffels & Vallet, Inc., of Detroit, engaged on design and supervision of plant construction at Paducah, and Sargent & Lundy, Inc., of Chicago, who are designing the high-voltage power-distribution systems and substation. The Carbide & Carbon Chemicals Co., a division of the Union Carbide & Carbon Corp., will operate both plant additions.

Natural Gas Pipeline To Service New Area

Following recent authorization of the Federal Power Commission, the Texas Gas Transmission Corp. will build a 408-mile pipeline to carry additional natural gas to homes and industries in an area from Louisiana to Ohio. The expansion program, which will cost an estimated $33,700,000, will permit transporatation of an additional 240,000,000 cu ft of natural gas a day to more than 30 distributing utilities in Louisiana, Arkansas, Mississippi, Tennessee, Kentucky, Indiana, Illinois, and Ohio. The 26-in. pipeline will be built in six sections from near Bastrop, La., to a point near Louisville, Ky.

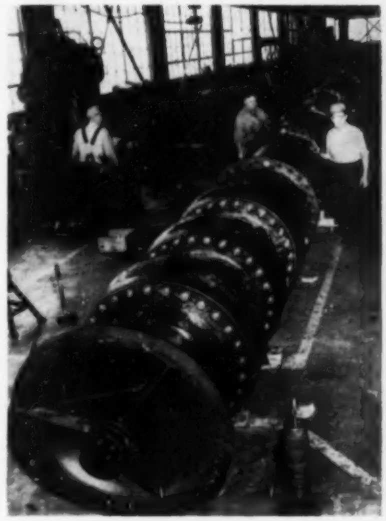
The project includes two new compressor stations near Shreveport, La., and Dillsboro, Ind., with a total of 26,860 compressor horsepower.

International Mapping Experts Meet in Washington

A cooperative mapping program on an international scale was outlined in a recent week-long International Mapping Conference held at the Army Map Service of the Corps of Engineers in Washington, D. C., under the sponsorship of the Assistant Chief of Staff, G-2, Department of the Army. The conference, the largest of its kind to be held in Washington, was attended by mapping experts from European countries engaged in a cooperative mapping program, as part of the western European defense plans.

Papers reviewing and analyzing work already accomplished on the overall international mapping program were presented by delegates from a number of Western European countries, with the objective of promoting greater coordination and standardization in mapping procedures and production. Col. John G. Ladd, commanding Officer for the Army Map Service, presided at the conference and, with other officials of the Service, presented the American position on the current international mapping program.

World's Largest Well Pumps Built for Rocket Research



Largest deep-well turbine pumps ever built are in production at Pomona, Calif., pump works of Fairbanks, Morse & Co. for use by Air Force in its rocket research program. Four of these giant turbine pumps are being installed at rocket research base at Tullahoma, Tenn. Each of 48-in. units is 42 ft long, weighs 30,000 lb, and can pump 25,000 gpm. Special 2,000-hp motor is required to drive each pump. In photograph one of mammoth pumps is contrasted with ordinary 6-in. turbine pump in foreground at right.

Seattle's Alaskan Way Viaduct Nears Completion

Construction of Seattle's $10,000,000 Alaskan Way Viaduct is speeded for completion late this year. Double-decked structure will provide $2^1/_2$-mile elevated north-south bypass of downtown Seattle and serve as artery for traffic on U.S. Highway 99. International LF-192 trucks equipped with concrete mixer bodies are playing major role in construction of project, which is largest municipal reinforced concrete job in city's history. Concrete is transported in $4^1/_2$-yd agitator bodies from central mixing plants to pouring sites where loads are emptied in buckets. Cranes, mounted on Gantry frames, then hoist bucketed concrete to project levels. Ralph W. Finke, M. ASCE, Seattle city engineer, is engineer on project, which is being financed by city, state, and Bureau of Public Roads. Major contractors include Morrison-Knudsen Company, Inc., and Rumsey and Company, joint venturers on one schedule, and MacRae Brothers of Seattle.

Construction Activity in July Reaches New High

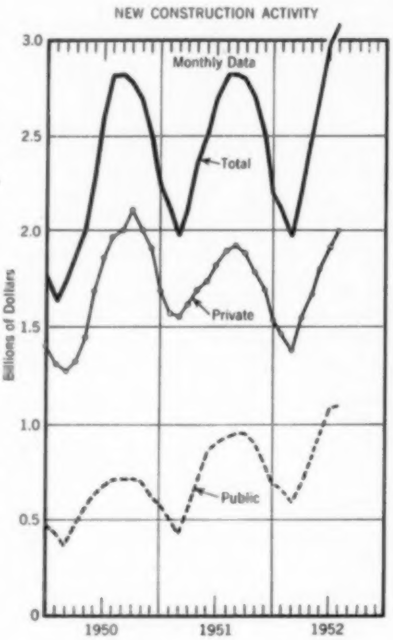
Expenditures for new construction in July reached the record total of almost $3.1 billion, according to preliminary estimates of the Building Materials Division of the U. S. Department of Commerce and the Labor Department's Bureau of Labor Statistics. The record dollar volume of work put in place indicated that the steel dispute had little adverse effect on the tempo of on-site operations during the month. According to the joint agencies, the full effects of the shutdown will probably not be felt until later months.

The July figure topped the June level by 3 percent and that of July last year by 7 percent. Seasonal advances in all major categories brought the private construction total to nearly $2 billion. Half the private total consisted of outlays for new residential building, which were up 4 percent from last July. In the public sector, defense construction remained at high levels. Highway construction, however, rose less than usual for the time of year because of small and spotty cutbacks in activity due to scarcity of steel. Even so, the dollar volume of highway work was 12 percent above the July 1951 figure. Total public expenditures for new construction amounted to $1.1 billion in July 1952.

New construction expenditures for the first seven months of this year, estimated at $18 billion, were about 5 percent above the amount for the same period of 1951. A slightly lower volume of private outlays was more than offset by a 24 percent increase in the level of public expenditures. Nevertheless, the 1952 total for private construction was twice as great as that for public—$12 billion, as against $6 billion.

Compared with a year ago, expenditures in the January-July period were down 6 percent for private residential construction and more than one-third for commercial building, despite recent increases. But factory building, despite the completion of important phases of industrial expansion, and privately financed public utilities showed substantial gains over the year.

Federal spending for military, atomic energy, and defense plant facilities was the most important factor in boosting the public construction total for the first seven months of this year. Highway construction, educational building, and conservation and development projects were somewhat above last year's levels for the comparable months, but outlays for sewer and water facilities were off 8 percent.



July construction expenditures reach record total of almost $3.1 billion, topping June level by 3 percent and July 1951 total by 7 percent, according to Department of Commerce curves.

Work to Start on Additional San Diego Water Supply

Relief for water-short San Diego County, California, is a step nearer with an announcement from E. A. Moritz, M. ASCE, director of Region 3 of the Bureau of Reclamation, that invitations to bid for the first stretch of the San Diego Aqueduct's second barrel are being issued by the Bureau. The contract will include construction of 31 miles of concrete pressure pipeline of 95-cfs capacity extending from near Hemet to Rainbow, Calif. The specifications allow 730 days for completion of the work.

Paralleling the first barrel, which was placed in operation in November 1947, the second barrel will start at the equalizing reservoir near the western outlet of the San Jacinto tunnel of the Colorado River Aqueduct. It will extend southward 71 miles to empty into the San Vicente Reservoir. The additional barrel will increase the rated carrying capacity of the aqueduct from 85 to at least 165 cfs, more than doubling its present annual capacity.

Construction of the second barrel is provided in an agreement between the Departments of the Interior and Navy. The Bureau of Reclamation will be in charge of the work, with funds to be provided by the Navy. Upon completion, the project will be turned over to the San Diego County Water Authority which, with the Metropolitan Water District of Southern California, will operate and maintain it. Repayment with interest is to be made to the government over a 40-year period.

Gulf Freeway in Texas Dedicated

Completion of the 50-mile Gulf Freeway between Houston and Galveston, Tex., was marked by dedication ceremonies on August 2. Construction costs of the $28,643,000 concrete superhighway were shared by the state and federal governments, with rights-of-way paid for by the City of Houston and Harris and Galveston counties. The first contract on the Freeway was let in 1946 for the first three-mile section within the Houston city limits. This three-mile urban section, plus another six miles that have since been completed, has already carried 252,000,000 vehicle miles of traffic.

Highway Definitions Adopted by AASHO

Availability of mimeographed standards of highway nomenclature, adopted by the American Association of State Highway Officials during the past few years, is announced by the AASHO. Parts I and II contain terms applicable to highway types and general highway definitions; Part III refers to traffic terms; and Part IV, adopted in January 1952, covers right-of-way terminology

The compilation, which is the work of a special AASHO Committee on Nomenclature, may be obtained from the Executive Secretary of AASHO, 917 National Press Building, Washington, D.C.

Aluminum Company Expands Its Davenport, Iowa, Works

A huge new rolling mill, costing approximately $4,500,000 and capable of producing extra-wide tapered sheet and plate for aircraft, will be installed at the Davenport, Iowa, works of the Aluminum Company of America in 1953. Equipment for the mill, which will be one of the largest and most modern in the aluminum industry, will be designed, installed and operated by ALCOA under the terms of a lease arrangement with the Air Materiel Command of the U. S. Air Force.

The Air Force will have first call on production of the new mill, which will be reversible and capable of rolling widths up to 10 ft through four-high stands of rolls, and of handling hot or cold ingots. Davenport was selected as the mill site because of the other ultra-modern facilities already there, such as large heat-treatment furnaces and wide continuous rolling equipment. Supplementary facilities, including an intermediate leveller and pre-heat and aging ovens, are provided for under the government contract to complement the rolling mill.

Important savings in time, money and materials with CONCRETE FRAMES AND FLOORS

Two views of Essex Apartment House in Indianapolis. Lower photo shows structural work at 9th floor, masonry work starting. Upper photo shows structural work at top floor with masonry work completed to 9th floor. Merritt Harrison, architect; Fink & Roberts, structural engineers; J. L. Simmons Company, contractor. All are of Indianapolis.

These photographs illustrate one of the outstanding advantages of reinforced concrete frame and floor construction. They show how frame and floor work proceed simultaneously. This enables masons, plumbers, electricians and other tradesmen to do their jobs as the structural work progresses and results in substantial savings in time.

Reinforced concrete construction also saves money and materials. It requires a minimum of critical materials. Forms can be reused from floor to floor.

Flat plate or slab band designs reduce or eliminate most of the headroom required for beams and girders in other types of construction. This saves about a full story in height on projects such as the above—with accompanying savings in masonry, partitions, stairs, conduits, ducts and piping.

Concrete frame and floor buildings are low in first cost, require little or no maintenance and give long years of service. The result is ***low annual cost.*** Such buildings also are sturdy, durable, firesafe.

For help in designing and building reinforced concrete frames and floors write for free, illustrated literature. Distributed only in U.S. and Canada.

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New York Firm Retained On Seine River Bridge

The New York firm of D. B. Steinman, M. ASCE, has been retained by a syndicate of French construction companies as consulting engineer on the proposed $20,000,000 Tancarville Bridge to be built by the Government of France over the lower Seine between Rouen and Le Havre. With a main span of 2,000 ft, the structure will be the largest in Europe.

The immediate engagement consists of completing the design of the cables, anchorages, and suspension system, preparing estimates of quantities and costs, and assisting the contracting companies to prepare detailed proposals and tenders. The official government specifications require the contractors to guarantee the aerodynamic stability of the structure.

New Nuclear Testing Facilities Authorized

Construction of facilities related to the development of nuclear propulsion for aircraft has been authorized by the U. S. Atomic Energy Commission. The new testing facilities, which are estimated to cost approximately $33,000,000, will be built at the National Reactor Testing Station in Idaho. Construction is scheduled to begin this summer.

Preliminary design studies for the AEC ground test station have been performed by the Parsons-Macco-Kiewit Company, Los Angeles, Calif., under a subcontract with General Electric. The Morrison-Knudsen Co., Inc., of Boise, Idaho, has been awarded a $107,242 low-bid contract for the construction and reconstruction of roads, and the construction of a disposal area at the National Reactor Testing Station.

Army to Build Seven Permanent Hospitals

Construction of the first of seven new permanent-type hospitals planned for Army posts in this country will begin early next year, according to a Department of the Army announcement. The new buildings, which will provide capacity for a minimum of 3,200 patients, represent the first step in an Army program to transfer patients from wooden, cantonment-type structures built during World War II to modern, multistory buildings. The largest of the new hospitals, to be erected at Fort Dix, N. J., will have a 750-bed capacity, expansible to 1,000 beds. Smaller installations are planned for Fort Benning, Ga.; Fort Bragg, N. C.; Fort Knox and Fort Riley, Kans.; Fort Belvoir, Va.; and Fort Monmouth, N. J.

Philippine Improvements Are Authorized by MSA

Earmarking of $6,000,000 in Mutual Security Agency funds for highway development in the Philippines and of $1,124,000 for flood control and drainage projects is announced by Roland R. Renne, chief of the MSA in the Philippines. The Philippine government will make an initial contribution of $2,000,000 to the road project, with more to be added as the work develops. The highway project will be confined largely to Mindanao Island. The flood control and drainage program will consist of 26 individual projects, including 14 in Luzon.

The MSA has also authorized the Philippine government to spend $590,000 for housing and food production projects and $225,000 for a laboratory and the improvement and expansion of production and distribution of rice and maize seed.

Soil Analysis Saves $100,000 on Power Plant Foundation

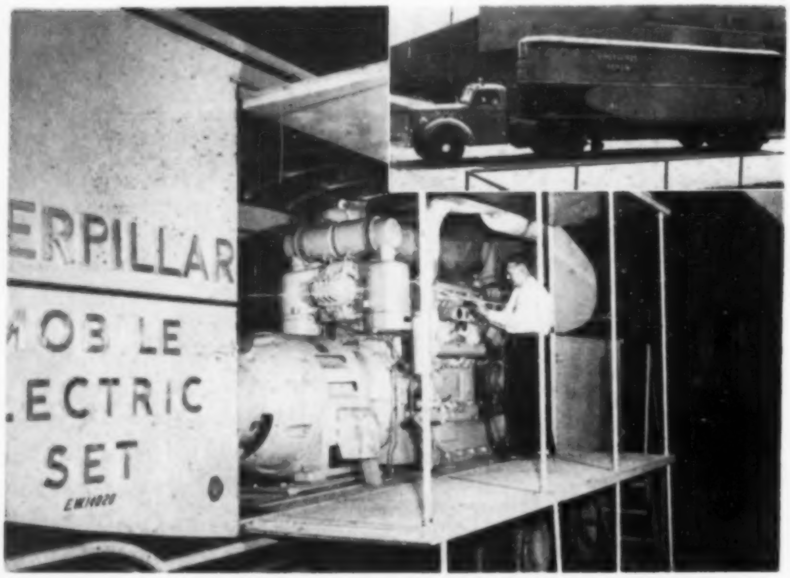
Although foundation costs for the new Pinopolis Steam Electric Generating Station at Moncks Corner, S.C., are more than half a million dollars, they are about $100,000 less than they would have been without the thorough soil analysis made by the low bidder on the job—the Daniel Construction Co., of Greenville, S.C., and Birmingham, Ala. Other contractors bidding on the job, which was designed by the engineering firm of Ford, Bacon & Davis, Inc., planned to use steel sheetpiling and a complete well-point system to keep water from an adjacent canal out of the excavation work, raising the cost of the work more than $100,000.

Though the bottom of the excavation was more than 14 ft below average water level and the foundation at one point only 20 ft from the bank of the canal, Daniel Company engineers, after careful analysis of the heavy Carolina marl soil strata, were convinced that it would form a wall adequate to hold back the canal water if the foundations could be gotten in with sufficient speed. It was found later that only two gasoline pumps were needed to keep the excavation dry enough for easy handling of equipment and materials.

The foundation is made up of a 9-ft-thick bottom mat of reinforced concrete, 130 by 216 ft, which contains a series of tunnels to handle cooling water for the condensers. The tunnels slope up through the concrete to the canal, further complicating work on the project. Concrete is being placed by Pumpcrete machines from a batching plant and an 800-bbl bulk cement plant. A continuous feed of up to 450 yd per ten-hour day is placed with vibrators between $1^1/_2$-in. reinforcing bars placed 3 in. apart. By vibrators $^3/_4$-in. aggregate with a $2^1/_2$-in. slump is then flowed into this mat in three layers.

Foundation of Pinopolis Steam Electric Generating Station at Moncks Corner, S.C., extends 42 ft below surface and 13 ft below canal bottom. Without aid of thorough soil analysis, no contractor would have dared risk project without steel sheetpiling which would have added about $120,000 to cost.

Mobile Electric Set Relieves Power Crisis



Recent power failure at South River, N.J., proves value of Caterpillar Tractor Company's new mobile electric set. To relieve overload on municipal power plant after breakdown of its main generator, emergency electric unit, shown above, was dispatched from nearby Philadelphia to South River, where it provided additional power needed to carry community through emergency. Set consists of 315-kw generator driven by 500-hp diesel engine, both mounted in van-type truck trailer. Output is 60-cycle alternating current, three-phase, on either 2,400 or 4,160-v transmission. Radio-telephone connection keeps unit in constant contact with the home office for continuous control in emergency areas.

Steel Exports in 1951 Went to New Markets

Sharp changes occurred in the amount of iron and steel shipped to foreign countries last year, according to a release from the American Iron and Steel Institute based on Department of Commerce data. Canada remained the largest importer of iron and steel products from the United States, receiving nearly 1.2 million tons, an increase of approximately 340,000 tons over 1950. Mexico was the second largest customer, taking 256,000 tons. These countries, with Cuba and some Isthmian nations, purchased about half the total tonnage exported as compared with 43 percent in 1950.

South America replaced Europe as the second largest consuming continent, receiving more than 588,000 tons in 1951 as compared with less than 400,000 tons the previous year. Venezuela purchased 198,000 tons, and Brazil 120,000 tons. Exports of iron and steel products from the United States to Europe came to 430,000 tons, 20 percent less than during 1950. Asia ranked fourth in 1951 with the purchase of 407,000 tons, more than one-quarter of it going to Iraq in the form of pipes and tubes.

Although the total tonnage exported in 1951 (3,277,000 tons) represented an increase of 14 percent over 1950 exports, it was lower than in any other year, except for 1950, since 1939.

Buffalo-Niagara Water Resources Held Ample

An abundant supply of water of good chemical quality is available in the Buffalo-Niagara Falls, N.Y., area, according to results of a survey recently reported by the U.S. Geological Survey. Use of water in the region for public and industrial supplies is about 1,700 mgd, or less than 2 percent of the potential supply of the region. The Niagara River, the principal source of supply, is capable of supplying 125,000 mgd—an amount sufficient to supply 70 percent of the estimated daily use of water in the United States for all purposes except power. Moderate supplies may also be obtained from smaller streams in the area, such as Towanda Creek and the Buffalo River. Groundwater sources supply about 15 mgd for public and industrial use, with additional supplies potentially available.

Free copies of the report, which has been issued as Geological Survey Circular 173, are obtainable on application to the Director, U.S. Geological Survey, Washington 25, D.C.

Decline in Housing Starts in June Noted

A total of 106,000 non-farm housing starts was made in June, according to preliminary estimates of the U. S. Labor Department's Bureau of Labor Statistics. Despite the fact that June was the fourth consecutive month this year in which more than 1,000,000 new, permanent non-farm dwellings unit were started, the June figure was exceeded substantially in 1950 and 1951 when a large number of publicly owned units were started. It also represents a decline of about 1,000 units from the May total.

The preliminary estimate of volume for the first six months of the year, placed at 567,500 units, is about 4 percent under the final January-June 1951 figure. Private housing starts alone totaled over half a million units (523,500) for the first half of the year—just 5,600 units under the 1951 volume for the same period. Publicly owned housing placed under construction this year has been declining in volume since March, and the total for the first six months of 1952 (44,000) units was 28 percent under the January-June 1951 total.

New Traffic Interchange Facilitates Turnpike Use

Recent opening of the final section of the Newark-Jersey City traffic interchange, including the bridge crossing of Raymond Boulevard in Newark, will expedite vehicular traffic to and from the New Jersey Turnpike. The interchange is one of the most important on the turnpike, serving the highly industrialized northern New Jersey areas. It provides access to and from the Newark business and industrial districts, the Bayonne and Jersey City area, and also the Holland Tunnel for traffic to and from downtown New York.

The number of vehicles using the turnpike in the first eight months of operation is 10,040,125, according to Paul L. Troast, chairman of the Turnpike Authority. This means a daily average of 46,000 vehicles—twice the number estimated. Revenues produced from tolls amounted to $9,007,571, which is also about double engineers' estimates.

(*More News Briefs on page 230*)

New Type of Bridge Built in Germany

Said to the only bridge of its kind in the world, this new center - supported one-carrier structure is being built for pedestrians across the Rhine-Herne Canal near Wanne-Eickle, Germany. The single supported structure is 200 ft long, and was designed by Wilhelm Haupt, of the Dortmund Brueckenbau Co. Wide World Photo.

N. G. Neare's COLUMN

R. Robinson Rowe, M. ASCE

History will record that the 150th meeting of the Engineers Club of Esseyeville was held in Chicago, as a part of the convocation of all distinguished engineering organizations upon the occasion of the Centennial of the American Society of Civil Engineers. But it won't record that Prof. N. G. Neare, Josephus Kerr and Calvin Klater discussed the serially quadriform phalanges of Numeropolis with Eulerian rigor and Gaussian precision.

"Say something, Joe," was the Professor's opening.

"A nice evening for phalanges," answered Joe Kerr. "I wish you'd check my equations before I tell you my answer. Using letters for the number of phalangites along the side of each formation, I wrote:

$$a^2 + b^2 = g^2;\ c^2 + d^2 = h^2;\ e^2 + f^2 = i^2 \quad (1)$$

$$a^2 + b^2 + c^2 = j^2;\ d^2 + e^2 + f^2 = k^2 \quad . \ (2)$$

$$a^2 + b^2 + c^2 + d^2 + e^2 + f^2 = m^2 = x \quad . \ (3)$$

That is, you ask that six pythagorean relations be satisfied in order to find x, the total number of phalangites?"

"That's right, Joe, and since I asked 'How many phalangites *must* there have been?', x should be a minimum."

"Which I can satisfy with $a = b = c = d = e = f = g = h = i = j = k = m = x = 0$," quipped Joe, "so that the whole parade was just a bad dream."

"Qwert yuiop etaoin shrdlu...." sputtered the Professor.

"Watch out for your blood pressure, Noah," warned Cal Klater. "Joe's jibe was born of defeatism. He should have written (2) and (3) as:

$$g^2 + c^2 = j^2;\ d^2 + i^2 = k^2;\ j^2 + k^2 = m^2 \quad (4)$$

so that his six pythagorean relations were of the pons-asinorum type. Then (1) and (4) can be satisfied in an infinite number of ways by synthesis, that is, in this case, by multiplying primitive sets like the 3-4-5 triangle by a square scale factor. For example, this set used twice with scale factors of 3^2 and 5^2 could give $9^2 + 12^2 = 15^2$ and $15^2 + 20^2 = 25^2$, satisfying the two equations involving *a-b-g* and *g-c-j*. Later these could be multiplied by still another scale factor if necessary in the satisfaction of the other equations. For a least set, I found $24^2 + 32^2 + 96^2 + 72^2 + 81^2 + 108^2 = 185^2 = 34{,}225$, the required number."

"Checking Numeropolis' unpublished population of 34,226, as the mayor stood alone in the reviewing stand," added Professor Neare. "My analytic method, while more direct than Cal's synthesis, is less fun, so I won't burden you with it. Now Joe and I are going to run out to see the Centennial sights while Guest Professor Flo Ridan assigns the next lesson."

"It's a lesson in laboratory hydraulics," explained Flo. "The differential orificometer consists of two cylindrical tanks, one above the other, discharging freely thru circular orifices cut in their bottoms. Cross-sectional areas are 6 and 2 sq ft, respectively, for upper and lower tanks, 3 and 4 sq in. respectively for upper and lower orifices. In a calibrated run, the stage in the upper tank dropped from 148.84 to 53.29 in. What was the final stage in the lower tank if it stood at 33.64 in. initially?"

[*Cal Klaters were: Richard Jenney, Flo Ridan (Charles G. Edson and also Guest Professor), and S. L. Dum (Thomas Borman). If the early deadline for this Centennial issue caught other contributions en route, they will be acknowledged in October.*]

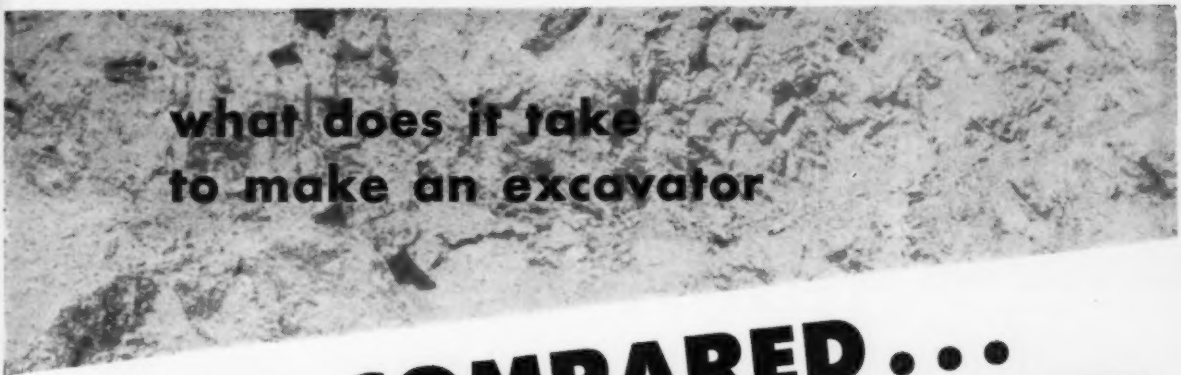
Contract Let for Signal Corps Depot Construction

Award of a $16,353,282 contract for construction of a U. S. Army Signal Corps depot at Tobyhanna, Pa., to the Merritt-Chapman & Scott Corp., of New York, is announced by Col. Walter Krueger, Jr., district engineer for the Philadelphia District of the Corps of Engineers. Major work under the contract entails the construction, complete with mechanical and electrical equipment, of 19 buildings with a total volume of about 50,000,000 cu ft, utilities, and site improvements. First work on the project, one of the largest in the United States, was started last June with the award of a separate contract for site grading and drainage.

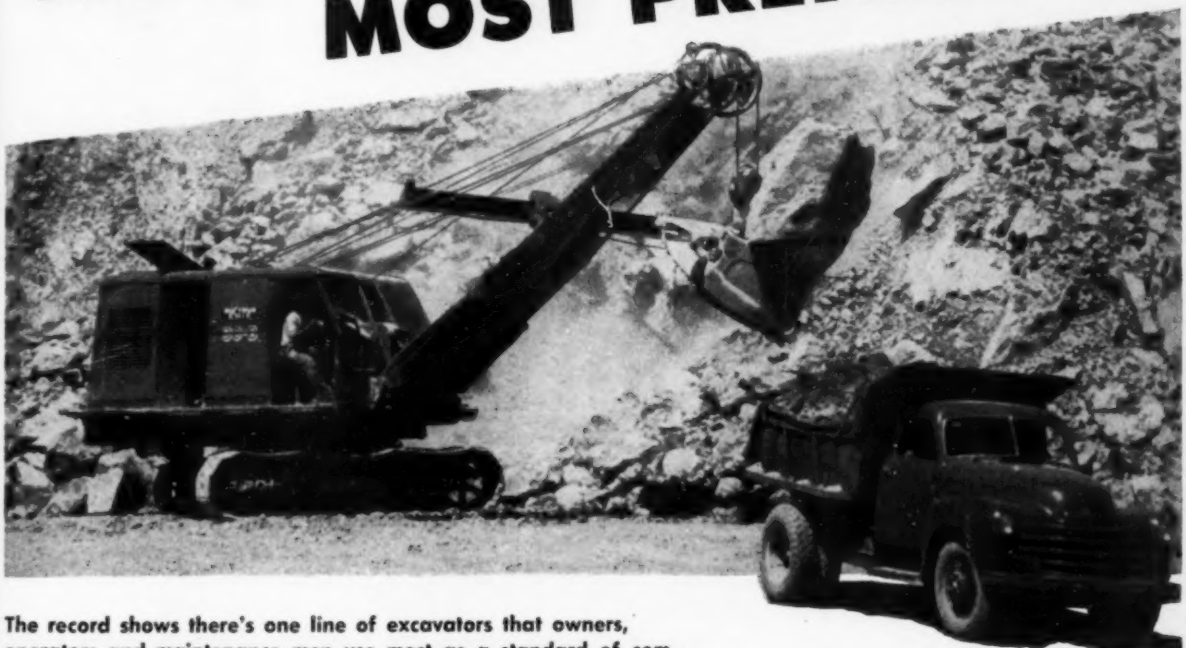
U.S. Air Force Expands Production Facilities

A general contract for the construction of new aluminum forging facilities at Newark, Ohio, for the U.S Air Force's heavy press program has been awarded to Darin & Armstrong, Inc., of Detroit, by the Kaiser Aluminum & Chemical Corp. The contract calls for construction of the principal heavy press plant and auxiliary buildings covering 360,000 sq ft, press foundations, and installation of machinery and equipment at an estimated cost of $11,555,000. Built on the site of the Kaiser Corporation's rod, bar, wire and cable works, the Newark plant is part of a $389,000,000 Air Force program for mass production of large aircraft parts with mammoth forging and extrusion presses.

Construction is scheduled to begin this summer and be completed in approximately 15 months. Smith, Hinchman & Grylls, Inc., of Detroit, is architect-engineer for the project.



MOST COMPARED . . .
MOST PREFERRED



The record shows there's one line of excavators that owners, operators and maintenance men use most as a standard of comparison . . . one line they prefer most. That's Bucyrus-Erie, and here are a few of the reasons why:

SIZE AND STRENGTH TO MATCH THE JOB. Seven different Bucyrus-Erie excavators are included in the 3/8- to 4-yard range of gas, diesel and single-motor electric machines. Each is designed as an entirely separate model. Materials and construction are specified for best results in each size. Complete facilities permit use of either welded or cast steel, plus special heat treatment, to meet design requirements and to provide extra long life.

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NEWS OF ENGINEERS

A. A. Anderson, former manager of the Highways and Municipal Bureau of the Portland Cement Association, has been appointed chief highway consultant of the Association, with headquarters in Chicago. Mr. Anderson has been with the organization since 1923.

E. G. Nielsen, assistant regional director of the U.S. Bureau of Reclamation, will succeed **E. A. Moritz** as regional director of the Bureau's Region 3 with headquarters at Boulder City, Nev. Mr. Moritz is retiring after service with the Federal reclamation program dating back to 1905, but will remain as a consultant to the USBR.

E. G. Nielsen

Guy Bonney is retiring from the engineering department of the Aluminum Company of America, Pittsburgh, Pa., and will make his home in Virginia.

Ralph N. Brescia, lieutenant, CEC, USN, formerly stationed at the U.S. Naval Hospital in St. Albans as resident officer in charge of construction of permanent hospital facilities, has been designated resident officer in charge of construction for the new Grumann plant facilities at Calverton, Long Island, N. Y.

William H. Correale is now serving as chief engineer in the Bureau of Construction of the New York City Board of Education, under **John P. Riley.** He was formerly connected with the firm of Moran, Proctor, Mueser & Rutledge of New York City.

W. W. DeBerard, Chicago city engineer, recently honored by Northwestern University, has also been awarded a distinguished service citation by Beloit University. Mr. DeBerard is an Honorary Member of ASCE.

Haywood G. Dewey, Jr., former executive officer of the 32nd Engineer Construction Group, now on the way back to the United States, has been awarded the Bronze Star for meritorious service in Korea.

Gavin Hadden, civil engineer, announces his change of address from 206 East Jefferson St., Falls Church, Va., to 1411 Key Drive, Alexandria, Va.

Harold W. Giffin, director and chief engineer of the New Jersey State Highway Department, Trenton, N.J., has been named chief engineer of the newly created State Highway Authority to construct the Garden State Parkway in New Jersey.

Barclay A. Greene, president of the Gunite Concrete and Construction Co., of Kansas City, Mo., announces the creation of a refractory linings division in the company.

Mark E. Thomas, consulting engineer of San Jose, Calif., is the new sanitation engineer for District 11 in Santa Clara County, Calif.

Herbert D. Vogel, colonel, who recently became division engineer of the Corps of Engineers' Southwestern Division at Dallas, also takes over as chairman of the Arkansas-White-Red Basins Inter-Agency Committee, and will serve as a member of the Board of Engineers for Rivers and Harbors, and as Department of the Army representative on the International Boundary and Water Commission for the Rio Grande.

William Whipple, colonel, engineer for the Third Army Headquarters, Fort McPherson, Ga., for the past year, has been assigned to the Chief, Army Engineers office in Washington, to become executive officer of the Civil Works Division.

Jonathan E. Teal, chief of the way and structures section, Railroad Transport Division, Defense Transport Administration, has been granted a six-month leave of absence to enable him to accept an engineering assignment with the Joint Brazil-United States Commission for Economic Development. During this period Mr. Teal will be an associate of Gibbs & Hill, Inc., consulting engineers of New York City, assisting in a comprehensive program for the development of power resources and the rehabilitation of the transportation system of Brazil as part of the Point IV Program.

Daniel A. O'Keen, associate engineer on leave from Malcolm Pirnie Engineers of New York, will go to the University of North Carolina this month to substitute for Prof. Herman G. Baity, now serving as head of the division of environmental sanitation, for the United Nations' World Health Organization.

Warren Mann, sales manager for Armco Drainage & Metal Products, Inc., Atlanta, Ga., has been promoted to the position of division manager, succeeding **Howard See.** Mr. Mann is now serving as president of the Georgia Section.

John J. Manning, vice-admiral, CEC, USN (retired) is retiring as president of James Stewart & Co., Inc., New York construction firm, and will be chairman of the board.

Sigmund Roos has resigned his position as head of the structural engineering department of Clarke-Rapuano, consulting engineers of New York City, and has opened an office for the practice of structural engineering. His office is located at 144 East 30th Street, New York 16, N.Y.

Ernest Couloheras, CEC USNR, was recently recalled to active duty. He was last employed as assistant chief engineer of the Board of Levee Commissioners at New Orleans, La.

Lynn W. Pine, colonel, Corps of Engineers, has recently assumed duties as assistant to the Deputy G-4 (Logistics), Department of Army, in Washington, D.C. Colonel Pine was formerly assistant chief of the Theater Branch, G-4 Plans Office.

John H. Porteus, until recently assistant chief design engineer in the machinery division of the Dravo Corp., in Pittsburgh, Pa., has been appointed chief engineer of the Luria Engineering Co. He will make his headquarters at the company's steel fabricating plant in Bethlehem, Pa.

Ren G. Saxton recently retired as head of the school of civil engineering at Oklahoma Agricultural & Mechanical College, a post he has held since 1923. He will continue his teaching duties as professor of civil engineering and act as head emeritus of the school. **Prof. Roger L. Flanders,** a member of the civil engineering faculty since 1925, has been appointed acting dean of the school.

Fred N. Severud, senior partner of the consulting firm of Severud-Elstad-Krueger of New York, has been awarded the Frank P. Brown medal of the Franklin Institute. Formal presentation will take place at the Institute's Medal Day ceremonies in Philadelphia, on October 15. He will receive the honor "in consideration of his outstanding engineering accomplishments in the field of building construction."

Joseph B. Converse, president of J. B. Converse & Co., Inc., of Mobile, Ala., is serving as a District Governor of Rotary International for 1952–1953.

Theodore J. Kauer, of Columbus, Ohio, has resigned as director of the Ohio State Highway Department, to accept appointment as chief engineer of the newly created Ohio Turnpike Commission on construction of a superhighway across the state.

George L. Blanchard and **Paul Rogers** are president and vice-president of a newly formed organization, Intercontinental Technical Enterprises, Inc., located in Chicago, Ill. The firm will specialize in the promotion and marketing of new engineering patents, methods, and practices which are well known and established abroad.

Leo H. Corning, manager of the structural and railways bureau of the Portland Cement Association, has been appointed director of promotion. **Thor Germundsson,** structural engineer with the Association, takes over Mr. Corning's former position.

William W. Carlton, head of William W. Carlton and Associates, engineers and architects of Cincinnati, Ohio, now on duty with the Military Construction Division of the Office, Chief of Engineers, has been designated the Department of Army representative to accompany members of the U. S. Senate Armed Services Committee on a tour of overseas bases.

Michael A. Spronck, former associate editor of *Contractors & Engineers Monthly,* now holds the same position on the staff of *Construction Equipment.* Mr. Spronck was also recently appointed editor of *The Transit,* the publication of Chi Epsilon.

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DECEASED

Former Vice-President, Henry J. Sherman, Dies

Henry John Sherman (M. '12) senior member of the engineering firm of Sherman, Taylor & Sleeper, Camden, N.J., died at his home in Moorestown, N.J., on July 29. He was 82. After graduating from Lehigh University in 1890, he served for two years in the engineering department of the District of Columbia, and four years in the Philadelphia Department of Public Works. He entered private practice in 1895, becoming a member of the firm of Haines & Sherman in 1900, and in 1923 head of the successor firm of Sherman & Sleeper. Mr. Sherman had served the state of New Jersey in several capacities—as chief engineer of the New Jersey Inland Waterways, member of the Board of Engineers on the Erosion and Protection of New Jersey Beaches, and consulting engineer to the Board of Commerce and Navigation. Mr. Sherman served the Society as Director from 1933 to 1935, and as Vice-President in 1949 and 1950, and had been president of the Philadelphia Section.

Henry J. Sherman

John Nagel (A.M. '10) retired civil engineer of New York, N.Y., died at his home on July 6 at the age of 77. For more than a decade he served as superintendent of the Manhattan Beach Estates. Mr. Nagel was connected at various periods with construction of such projects as the Boonton Reservoir, the Clayton (N.J.) Central School, and the sea wall at Long Beach. He received his education at the City College of New York.

Charles Frederick Parker (M. '12) retired engineer of San Antonio, Tex., died on May 22, at the age of 78. Engaged in private practice in San Antonio during his entire career, Mr. Parker was the head of Charles F. Parker & Co., dealers in building materials and contractors' equipment. He was a graduate of the Sheffield Scientific School of Yale University.

Sigurd Olai Rogde (A.M. '30) engineer with the American Gas & Electric Service Corp., New York, N.Y., died recently. He was 67 years old. From 1919 to 1923, Mr. Rogde was associated with the Electric Bond & Share Co.; from 1923 until 1930 with the International Paper Co., as design engineer; and from 1930 to 1933 with the Anglo Chilean Nitrate Co., of New York. He was then

(*Continued on page 244*)

All-welded viaduct . . .

This article begins on page 180

(*Continued from page 185*)

present-day mill practice, it is impracticable to make a four-side inspection the surface inspection is made after arrival at the fabricating plant. The steel is also checked, after arrival at the fabricating shop, for heat numbers and surface imperfections. Before starting fabrication all shop equipment is checked to see that it is adequate to handle the job.

The contract requires that all workmanship shall conform to the Standard Specifications of the Division of Highways, which in turn require that all welding, the welding procedure, and the qualifications of operators conform to AWS Standard Specifications. In these specifications the use of low-hydrogen rod and of semi-automatic and automatic submerged-arc welding is required. All welding operators are given sufficient time to practice and master the necessary technique for this type of welding.

Before any welding is performed on the main structure, a procedure test, composed of destructive and non-destructive tests, is required. This test consists chiefly of checking the deposited metal for soundness and structure.

Preheating, as specified on Unit 1 of the structure, ranges from removing the chill up to 300 deg F, being governed by the thickness of metal, design, and the rate of cooling. The preheating temperature was controlled by the use of Tempilstiks (a waxlike crayon, which has a rated melting point) and a surface contact pyrometer.

The workmanship is controlled by standard shop practices. Experienced personnel supervise the fabrication. Practical methods are used to assure good welding. Welding inspection consists chiefly of nondestructive testing, mainly using the radiograph, trepanning, dye-check, and hardness limitations.

The gamma ray is used in the shop whereas the X-ray is used in the laboratory. A portable Brinell hardness tester is used to control the hardness in the welded area.

To maintain a minimum moisture content in the low-hydrogen rods, the shop has provided ovens which are maintained at 300 deg F. The rods are stored in these ovens for at least 2 hours before being removed for use. For field welding with the LH rods, it is proposed to use portable ovens that can be taken to the site of erection.

Welding Here to Stay

Welding in the field of bridge construction seems to be here to stay. It is one of the major construction tools in the hands of the structural engineer. Since the science and knowledge of welding are changing and moving forward with great rapidity, structural engineers should be too progressive to delay using welding as a structural tool until the last word has been written on it. Any hesitancy would be like waiting to build the first Ford until automotive engineering had advanced to its present status.

Structural welding has many desirable and economical applications. However, other types of fastenings such as rivets or high-tension bolts should be given full consideration for each particular design. The structural engineer's greatest needs today in the use of welding as a tool are the following:

1. A revision in the properties of ASTM A7 steel to make it more acceptable for welding.
2. A specification for welded construction that covers the automatic and semiautomatic submerged-arc process as well as hand welding.
3. A specification for heat treatment of structural members that is practical and economical for shop fabrication.
4. An acceptable specification for fabrication tolerances like that previously set up for rolled shapes.
5. A standard and uniform practice of shop inspection and testing so that fabricating shops can estimate their costs with greater confidence.

With the completion of all the units of the Division Street Interchange structure, it is hoped that a contribution will have been made toward the practical application of welding as a tool for the structural engineer.

(*This article is based on the paper presented by Mr. Hollister before a joint session of the Structural Division and the American Institute of Steel Construction, presided over by R. N Bergendoff, member Executive Committee of Structural Division, at the Centennial Convention in Chicago*).

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Robert E. Judge, Concrete Contractor, Bellwood, Illinois

400 concrete foundations were expertly framed in record time with Symons Forms. "Weather and material permitting, these 25′ x 32′ foundations were set up in four hours by three men," stated the contractor. This rapid, economical means of form erection can be accomplished because panels are standarized and the erection hardware, which consists of three basic pieces, is easily secured.

Reinforced Forms for High Walls, Fast Pours

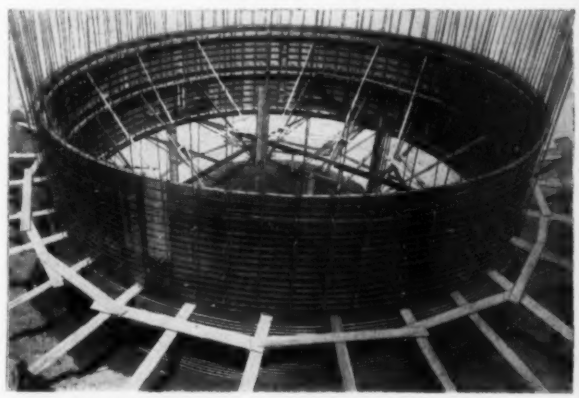
James Stewart, General Contractor, Chicago, Illinois

Pouring of these high walls with pressures from 650 to 1500 pounds per square foot required Symons ¾″ Plywood Forms with steel ribs every 12″. These heavy duty forms allowed the use of additional ties where the pressure was the greatest. Setting up and stripping was executed at the lowest possible cost due to the Symons System of securing forms and ties in one operation.

Setting Up Forms on a 16′ Battered Wall

James Leck, General Contractor, Minneapolis, Minnesota

Ties were placed in position when outside forms were erected. After erecting steel, inside forms were set in place and secured to the ties. Battered walls are handled similar to vertical walls, the only difference being the variance in the length of ties. Symons provides any special length ties promptly at little or no extra charge. Scaffolding was secured with standard hardware.



Setting Up Forms for Sewage Disposal Tank

G. L. Tarlton, General Contractor, St. Louis, Missouri

Steel rib panels with V shaped fillers at each joint were employed. The connecting bolts used in joining two panels and for anchoring ties pass through these fillers. Reinforcing is placed prior to locking of outside forms to panel ties. Symons Forming System is a simple method of forming that is adaptable to straight walls, battered walls, curved walls and slabs.

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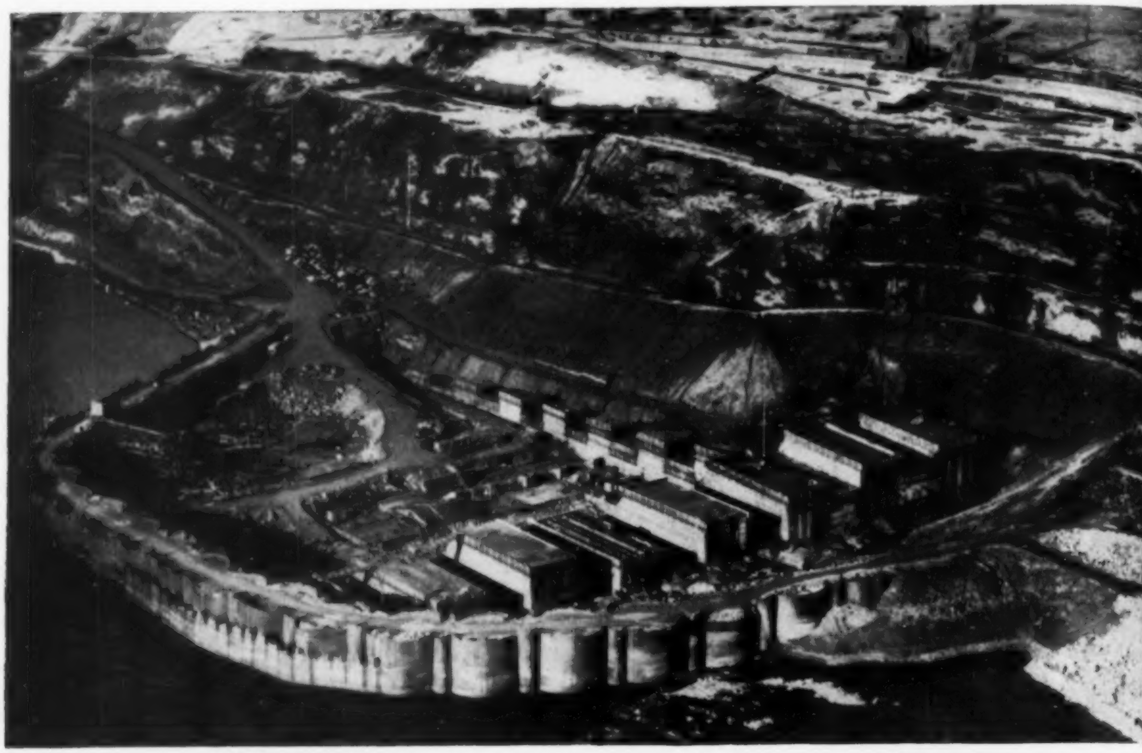

LOOKING NORTHWEST from the air, this view shows construction progress on training wall, stilling basin and spillway monoliths at Chief Joseph Dam near Bridgeport, Wash. Cells of U·S·S Steel Sheet Piling keep the construction area unwatered.

Water Law in the U.S. . . .

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water from further non-federal acquirement on a basis similar to that under which public lands may be withdrawn from further entry. This claim should have been fully answered by its rejection by the United States Supreme Court in Nebraska v. Wyoming (325 U. S. 589).

Government Asserts Authority

More recently the Federal Government has asserted its "paramount authority" over all waters and has recently filed suit to establish such authority on a California stream in a proceeding known locally as the Fallbrook case. To date this controversy has been the subject of extensive outcry in the public press and has not reached the courts.

Another development in recent years has been the so-called "valley authority" program for the completely integrated use of all water within a stream basin, as illustrated by the Tennessee Valley Authority. Advocates of controlled development and planned economy have been active in seeking the creation of similar authorities in several western drainage areas. To date advocates of the existing system of private development, supplemented by federal aid on those projects beyond the scope of local resources, have succeeded in preventing the radical changes that would occur if the Federal Government were to dominate water development and use in our arid states. Water plays a vital part in the economy of these areas.

Supplanting our present policies and laws by the directives of a federal agency would be the equivalent of replacing our present system of local government in the water field and practically eliminating local control. As the halfway point in the development of our western water resources has been reached or passed, those having present rights to the use of water are deeply concerned over the way such rights might be affected by the establishment of a completely new and independent federal system. The preservation of recognized rights is as important to our arid states as are projects to develop our remaining unappropriated water supplies.

Strength of State Administration of Water Laws

Efforts to transfer the control of all waters to some federal agency are a natural outgrowth of the entry of the Federal Government into the construction of projects to develop water resources. Although state control of water use would be essential even if the Federal Government had remained an impartial party in water use, such state control has become even more necessary now that the Federal Government has acquired a major proprietary self-interest through its investment in federally constructed projects.

A major element in the strength of state administration of water laws has been the absence of any extensive self-interest on the part of the states in individual projects. Should any state undertake extensive construction of water projects, it would materially decrease its usefulness as the adminis-

trator of use of water by non-state projects. The Federal Government is now so deeply involved in water development in the western states that it cannot act as an impartial judge between its projects and those of local origin.**

The creation of valley authorities in western basins is being actively resisted by nearly all states and by local water interests within the basins. It is noticeable that nearly all promotion of such authorities has come from federal sources, either directly or indirectly. The decision as to whether or not such a radical change as that represented by a change from local control to federal authorities should be made is too important to be adopted on the basis of the self-interest of those desirous of becoming the administrating employees of the federal agencies.

National Water Policy

Closely allied to the principles of title to the use of water are the public policies relating to its use. Present federal policies relating to water are generally recognized as confused and in some cases contradictory. The need for reconsideration and revision of national water policies has led to the recent report on this subject by the President's Water Resources Policy Commission.

During the period this commission was preparing its report, the Engineers Joint Council prepared and issued a report setting forth its views in this field. There is a greater need for a redefinition of federal water policies than there is for revision and changes in water laws. It is hoped that progress in other matters now requiring the attention of Congress will soon permit it to give constructive consideration to this urgent subject.

Needs in Field of Water Law

No system of water law can be completely equitable in all its applications. In this, water law is no different than the other branches of the law of property. Perfect systems of law cannot be devised by human beings who themselves are not perfect in their aims and activities. In spite of these conditions we now have a generally good and workable body of water law well adapted to the needs to which it is applied. None of its possible defects furnishes justification for radical changes or departure from the established state and federal relationship in this field.

After 45 years of experience in the field of water-rights procedure in most of the western states, I am thoroughly convinced that present practices are well adapted to our arid areas. Under these practices progress may appear at times to be slow. This is the result of the caution with which proposals for change are considered. Experienced water users in the western states have become skeptical about the gains that it is claimed can be secured from radical changes in our present basic principles of title to the use of water or programs for restricting present practices of local control. The field of water law in the western states is not static and healthy progress is being made in meeting changed conditions as they arise.

(This article is based on the paper by Mr. Harding presented at a session of the Irrigation and Drainage Division presided over by W. E. Blomgren, M. ASCE, at the Centennial Convention in Chicago.)

DECEASED

(*Continued from page 238*)

with the M.W. Kellogg Co., of New York, and since 1938 had been with the American Gas & Electric Co. Mr. Rogde received a civil engineering degree from Cornell University in 1919.

Dudley Tibbets Corning (M. '15) retired civil engineer of Philadelphia, Pa., died there on June 17 at the age of 75. Mr. Corning had been with the Philadelphia Department of Public Works for 34 years, serving as head of the highway bureau from 1928 until his retirement in 1949. Earlier he had been with the coal lands evaluation division of the U.S. Treasury Department, and was chief engineer of the Cambria Steel Co., of Johnstown, Pa. Mr. Corning was a graduate of Rensselaer Polytechnic Institute.

William Henry Ellis (Aff. '21) president and treasurer of W. H. Ellis & Son Co., engineers and contractors of Boston, Mass., for 40 years, died there on July 20. He was 68. Before joining his father's company, Mr. Ellis was employed in the engineering department of the Boston and Maine Railroad. He served as a member of the State Committee on Port Facilities and as chairman for the Board of Appeal for the City of Boston.

Applications for Admission to ASCE, July 26–August 2

Applying for Member

Morris Eskiel Adelstein, Denver, Colo.
Alfredo Dudley Bateman Quijano, Bogota Colombia.
Hugh Hume Dixon, London, S.W., England.
Harold Keith Griffith, Keyser, W. Va.
James William Hall, Houston, Tex.
Dana L. Hannan, Indianapolis, Ind.
Paul Orpheus Haring, Los Angeles, Calif.
Otto Jurgens, Omaha, Nebr.
Alexander Harry Kenigsberg, Nashville, Tenn.
Muhammad Sadiq Khan, Denver, Colo.
Demetre E. Papanicolaou, Athens, Greece.
Abraham Pikoos, Wilmington, Del.
John Alexander Ruhling, Washington, D. C.
Alex Alexander Sirel, Chicago, Ill.
Harold Edwin Sprague, Ft. Belvoir, Va.
Irving Aaron Sussman, New York, N. Y.

Applying for Associate Member

Jorge Barriga, Olympia, Wash.
Paul Denman Doubt, Washington, D. C.
Sol Gonchar, Savannah, Ga.
Richard Smith Goodwin, San Diego, Calif.
Ramnathapur Keshavamurthy Keshava Narayan, Bangalore, India.
Claudio Manfrini, Sao Paulo, Brazil.
Suprovat Mitter, Bihar, India.
Vishnu Trimbak Mone, Ahmedabad, India.
Irene Esther Ryan, Anchorage, Alaska.
Aziz Aly Ismail Shahwan, Aberdeen, Scotland.

Applying for Junior Member

William Roy Chaney, Kansas City, Mo.
Alfonso Jose D'Santiago, Iowa City, Iowa.
Jorge Ferreira da Silva, Sao Paulo, Brazil.
Ivan Anderson Gaggin, Victoria, Australia.
Ira Augustus Hunt, Jr., West Point, N. Y.
Earl John Joseph Kramer, Mobile, Ala.
William James Lemessurier, Boston, Mass.
William H. Levelius, Jr., Milwaukee, Wis.
John William McCutchen, Shreveport, La.
Alfred Henry Mueller, Denver, Colo.
William Arthur Schmid, Jackson, Minn.
Bulent Servet Tasman, Ann Arbor, Mich.

[*Applications for Junior Membership from ASCE Student Chapters are not listed.*]

Suretyship . . .

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trouble, and the advice of such men has often averted substantial loss and delay to all the contracting parties.

In addition to the cost reducing and loss preventing by-products of a bonded competitive system, there is the accumulated know-how of decades of underwriting. There are certain businesses, just as there are certain individuals, whose job in life is to sit by the side of the road, so to speak, and be a friend to man. Under such circumstances, their "scale of observation" becomes broader than other men's, and their knowledge and guidance of more than ordinary value. Suretyship is such a business.

Joint Ventures Made Possible

It was suretyship, for instance, which instigated and made possible the joint venture as we know it today. This American way of getting things done by cooperation came into its own some years ago, when contractors and engineers were approaching what was probably the greatest single construction project undertaken in the history of our country—Hoover Dam. As originally contemplated, seven years were to be required for the completion of the dam, and the contractors were in effect guaranteeing that their estimate of price would stand against all the "changing conditions" of that period. A bond larger than any that had ever been previously written was furnished on this project to back the contractors, combined in a group known as the Six Companies Inc. As one of that outstanding group recently stated:

> Success of that monumental undertaking established a permanent strong relationship between bonding companies and western contractors that endures today as a progressive, yet stabilizing factor, insuring the contractor's responsibility to the public and minimizing unsound and unprofitable practices.

Since that time, the joint venture has become commonplace. The surety business believes it to be a good practice. We are proud of the part that surety know-how played in the inauguration of an era of huge construction projects, and we hope such projects will continue.

The final and perhaps most important by-product of contract bonds has been the stabilization of construc-

tion, for construction is a great basic industry, and its continuing success is vital to our national welfare and economic stability. One of the major objectives of the Associated General Contractors of America is called "risk parity" which is defined as "to place the business risks assumed by general contractors as nearly as possible on a parity with the risks assumed by other production industries."

Product Is Unique

The reason for the lack of risk parity, of course, is that most production industries sell a standard product by adding a profit after costs are known, while in construction there is an agreement to deliver a nonstandard product at some time in the future at a price fixed before construction is commenced. In short, contractors deal in futures, and any market analyst will tell you the hazards inherent in that practice.

One of the major ways in which contract bonds promote risk parity is by the elimination of the unqualified. Indeed, were it not for the necessity of qualifying for a bond on public works, the probable chaos which would result in the contracting industry from irresponsible bidders simply beggars description. We admit of course that unqualified contractors occasionally obtain bonds. Mistakes we have made and mistakes we will make, since underwriting, like estimating, relies on factors of judgment and there never will be a time when contractors, engineers, and underwriters will be infallible. Actually, in view of the magnitude and complexity of the construction industry, the miracle is that more mistakes do not occur.

In other words, there is a balance of power in the construction industry which is similar to that in our own Federal Government. Engineers, like Congress, draw the plans; contractors, like the President, execute them; and sureties, like the courts, see that both protect their rights and perform their duties.

Bonds for Bigger Jobs

To be stable, however, is one thing; to be static is another. The construction industry has traditionally been one of intense competition, and no good contractor would want it otherwise. To support this competitive system, it is sometimes necessary to bond contractors on jobs, the magnitude of which they have

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Highway maintenance . . .

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mud-jack is used primarily to fill voids under concrete pavements which have been developed by "slab pumping."

"Slab pumping" first was noted and recognized several years earlier, but not until 1939 and 1940 did soaring traffic loads begin to take their terrific toll on our highways and to mark this condition as a major maintenance problem. As the condition developed, particularly on the older pavements, it took only a short time to prove that mud-jacking and concrete replacement would not suffice.

Undersealing Developed

Again experimentation began. In 1942, or possibly 1941, Ohio began to experiment with the pumping of a low-penetration asphalt under the pavement, instead of soil-cement slurry, to control slab pumping. The practice was further developed in other states and is now known as "undersealing." It is at present considered a highly successful method for controlling this difficulty.

Another operation, largely perfected in the early 1940's, was the upper-decking of existing cold-mix bituminous surfaces. Previously, when a thin bituminous surface was to be renewed, it usually was scarified, and the old surface remixed and relaid. About 1939, however, a system of windrowing new materials on top of the existing surface, mixing them with bitumen, and spreading the mixture as an upper deck was adopted, thus adding to the thickness and strength of the surface as well as retaining the compaction of the original road. This procedure has proved worth while and still is practiced in road-mix resurfacing.

Emphasis on Reconstruction

Emphasis on reconstruction also came during this period. The breakdown of many of the older pavements occurred at a speed too fast for repairs by undersealing and full-depth patching, and to such an extent that merely repairing the pavements was not economical. Lack of funds made wholesale replacement impossible. This resulted in a widespread use of hot mixes to resurface old concrete pavements, such work being done primarily on a contract basis with most satisfactory results.

The truck, which is used for the transportation of men and materials, and for pushing snow plows and pull-

ing under-body blades, drags, light blade graders, pull mowers, and other maintenance units, is the most commonly used piece of maintenance equipment today. The next most popular unit is probably the motor grader, which is used for blading surfaces, cleaning ditches, trimming back slopes, mixing and laying bituminous patches and surfaces, and many other vital maintenance operations. Its forerunner was the split-log drag. Next in line of evolution was the small-wheeled blade grader pulled by horses or oxen, then the larger-wheeled grader pulled by tractors, and finally today's self-propelled motor grader, a most efficient machine in the hands of a skilled operator. Many, many other pieces of equipment, and small tools far too numerous to mention, have been developed and are being used in the maintenance of today's highways.

Personnel Training Raises Efficiency

Thus far attention has been given primarily to the part money, machinery, materials, and methods have played in the history of highway maintenance during the past century. Let's not overlook the all-important fact that highway maintenance involves the proper blending of a fifth factor. There must be well-trained men—who enjoy their work.

During World War II, it was found necessary to use substitutes for critical materials. Likewise, one piece of machinery had to take the place of another that was not obtainable. That period of substitution proved, most highway engineers will agree, that there is no substitution that can be made for the knowledge and ability of a trained highway maintenance man.

Today a maintenance man must have a wide knowledge of the use of many materials such as asphalt, tar, portland cement, aggregates, and chlorides. He must have personal skill in the operation of many pieces of equipment such as the truck, motor grader, concrete mixer, bituminous distributor, power mower, power shovel, and many other units. Last, but certainly not least, he must be able to work with men and to meet the public.

Maintenance and Public Relations

The maintenance man, by the very nature of his work, comes in very close contact with the public. How well he does his job determines to a very great extent the attitude of the road user toward the entire highway program. Thus, despite the highly

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Irrigation . . .

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purpose project in the United States is a public service rather than a private service; its ultimate goal must be that it is useful to the man on the ground, and an asset to the nation.

The Federal Reclamation Law of 1902 created the principle of repayment by the beneficiaries which, in turn, quite naturally resulted in a close degree of scrutiny of project plans by irrigation district officials and their consulting engineers. This scrutiny is highly welcome. In addition, and as a result of succeeding laws, executive orders, and interagency agreements which have been adopted primarily in the last fifteen years, the Reclamation Bureau cooperates with many other federal, state, and local agencies in the development of its plans. They each have an opportunity to review or participate in the investigations as the work proceeds, and to review the final report when it is ready. No less than a dozen agencies participate in one way or another on a simple project, and as many as forty groups review the plans of proposed major river basin developments.

The federal policy is that as soon as a local irrigation district is capable of undertaking it, the district takes over the operation and maintenance of the irrigation works. It is also federal policy to take such steps as are practicable to avoid speculation in lands that are expected to be put under irrigation.

The idea is fast becoming accepted in the United States that an undeveloped resource (especially an undeveloped, renewable resource) is not a resource in the bank. It is a resource being wasted.

Hydroelectric Power

In connection with the disposition of hydroelectric power, it is the policy to so transmit and dispose of such power as to encourage the most widespread use of it at the lowest possible rates consistent with sound business principles. The Federal Government also encourages, as a matter of both law and policy in connection with irrigation projects, the development of family-sized farms.

Further, water rights for all federal projects are secured in accordance with the laws of the states in which the projects are located, thereby recognizing the rights and privileges of the states with regard to the

development of their natural resources.

Benefits

Generally, benefits fall into two categories, direct and indirect, and there are many in each. There is general agreement in the United States on the kinds of direct benefits, and how to measure them, but a somewhat spirited discussion is in progress on how to measure indirect benefits. Everyone agrees that they are there, but not on how to evaluate them. Any appraisal of the social and economic implications of irrigation development encompasses consideration of both the direct and the indirect benefits.

An illustration of the indirect benefits, the economic effects of a project on other parts of the nation, comes from a project in Idaho where in 1949 approximately 40 percent of the volume, and 72 percent of the value, of all railroad freight shipments into the project area came from the 37 states east of the Rockies.

The "General Conclusions" set forth in the June 1950 report of the Water Policy Panel of the EJC presents a startling contrast to these federal policies.

The report is the result of careful work and contains many constructive recommendations. However, there are certain influences that I should like to mention, for they follow a strictly banker approach, as compared to existing national policy. To be specific, I shall quote a few statements from the EJC policy report:

> In its performance of its second function (to aid in the cost of financing the construction of works) the Federal Government is basically acting as a banker responsible for the soundness of his loans.
>
> Except for meeting the needs of the Federal Government, authorizations for federal hydroelectric power construction should be predicated upon a cash income to the Treasury from the sale of power.
>
> Except where absolutely essential for its own needs, the Federal Government should engage in the transmission of power only when and where necessary in order to attain higher net income to the Treasury. . . .
>
> In the cases of federal revenue-producing water developments, the principle should be extended to provide for the payment of state and federal income excise taxes or their equivalents.
>
> . . . secondary benefits should not be lumped with direct offsets to cost to determine the feasibility of any particular project. . . .

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Construction by contract . . .

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through which investments can be made in facilities which serve people.

The construction industry has kept pace with and helped in the development of practically all other industries, and is able to make use of their discoveries to build constantly better facilities with greater speed and efficiency.

Labor has also kept pace with the development of new materials, new and greater designs. Workmen have had to be continually trained in new techniques while preserving their ancient skills. This has been done under a comprehensive program. American workmen have fully measured up to the challenge.

The industry is of huge size, and produces an amazing variety of products under every conceivable circumstance, yet its methods and internal organization have developed, often with growing pains, until they are of such flexibility that the industry can execute any structural need of the people any place in the world.

By experimentation through the years, and now by cooperation between such organizations as the American Society of Civil Engineers, the American Institute of Architects, The Associated General Contractors of America and many others, there has developed a type of joint, cooperative relationship within the construction industry which best fits its purpose, and which permits fair and equitable treatment of all those who are connected with construction operations.

As general contractors, who are the logical development in the industry to fulfill the need for organizations to take complete responsibility for the construction of projects and to correlate all the skills, materials and machinery required, we look forward to an even greater century in partnership with engineers.

The engineer's qualities of skill, imagination, and courage have been complimented by the initiative of the contractor in devising new methods, and together they form a team which today continues its advance toward an ever expanding vision of a greater United States of America.

(*This article was prepared from Mr. Foreman's address at the Construction Luncheon at the Centennial Convention in Chicago.*)

Engineer manpower . . .

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Society looks to the engineer to bring about all these miracles. It is a responsibility that the profession must assume.

It does not seem necessary to further support the view held by a great many people that the peacetime needs for engineering services are accelerating rather than diminishing. The amount of engineering required per unit of population continues to increase, while the supply of engineers, and hence the number of engineers per unit of population, is likely to remain fixed. This is shown in Fig. 2, in which the line A-A indicates the estimated limit of the supply.

Engineers Must Be Better Trained

An adjustment seems inevitable to accomplish the engineering work that must be done by the limited number of engineers expected to be available. This adjustment lies in the direction of better utilization of engineers. To a considerable degree, engineers have been used for subprofessional work. In fact, some engineers are not trained to perform functions much above the subprofessional level. In future, it will be increasingly necessary to use engineering aides to extend the service of the professional engineer in much the same way that therapists, nurses, and laboratory technicians are used to extend the services of the doctor.

A corollary to this principle of readjustment is that engineers generally must be better trained. As each engineer must extend himself over more territory through the aid of others, it will be essential that he be trained at a higher level in order to do such directive work effectively.

Such a rearrangement of engineering services will result in an improvement in the social status of the engineer, and will increase his value to his employer—which in turn will improve his economic status. At the same time, it seems certain that engineers will be obliged to function more and more in circumstances involving economic and social factors along with the more conventional economic and technical factors. The future holds promise for the entire profession. The increasing opportunities for service to the community will be more richly rewarding in terms of personal satisfaction and remuneration. It may be truly said that the profession is about to come of age.

High-strength bolts . . .

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gradual slip associated with maximum design loads long sustained at painted contact surfaces, the continued use of ordinary unfinished bolts may offer the most practical solution. However, considerable test data are already at hand to indicate that high-strength bolt values, considerably larger than those now recommended even for rivets, might be justified if the resistance to shear of the bolt alone is the criterion of useful service. Such would be the case where a slip of, say, $^1/_{16}$ in. is of little importance and the bearing area on the side of the bolt hole is adequate. Comparing this possibility with the present *reduced* values prescribed for unfinished bolts, it is conceivable that there is an economic place for high-strength bolts even where less expensive unfinished bolts have up to now been used exclusively.

High-strength bolts are also useful in resisting applied tension-producing loads. This feature has not yet been covered in the Council's Specification, but structural engineers have for many years taken advantage of the possibilities which these fasteners offer in the solution of problems of this type. It is obvious, on comparing the minimum elastic proof and ultimate breaking loads specified for A-325 bolts with corresponding calculated values for rivets of the same nominal diameter, that the loss of stress area in the threaded part of the bolt is more than compensated by the superior physical properties of the bolt material, leaving a very comfortable margin of extra tension-resistance capacity per fastener.

In the absence of any accepted standards, various working values have been used by structural engineers in proportioning high-strength bolts for tension-type connections. The writers know of no case, however, where these bolts have been deliberately prestressed in tension substantially above the calculated stress which they would be required to resist in service, even though it is a well-known fact that the endurance limit of bolts under cyclic loading is vastly improved when the fluctuation of stress is at a minimum.

Obviously, if some of the bolts in a connection (required to transmit "shear") are to be tightened nearly to the elastic proof load, the problem of field control of the bolt installation will be simplified if all high-strength bolts are so tightened, including those required to resist applied tension. This practice of highly prestressing bolts which are to carry tension loads in service is one which has long been recognized as beneficial in other fields of engineering. A program of static and fatigue tests on typical tension-type building connections, expected to demonstrate the beneficial effect of a high prestress, has recently been given a high priority on the Council's continuing program of research. Until test data are in hand, the Council has preferred to remain silent on the question of suitable working stresses.

(*This article is based on the paper by the authors presented before the Structural Division session presided over by E. C. Hartmann, a member of the Structural Division's Executive Committee, and Douglas McHenry, a member of the Engineering Mechanics Division's Executive Committee, at the Centennial Convention in Chicago.*)

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As to new projects, in general there should be no further authorization until a uniform national policy has been adopted.

It is obvious that this report sponsors a banker approach, as compared to a resource-development approach. It would emphasize the profit motive in federal undertakings, rather than the present objective of broadening the resources use and economic base of the nation. It would seek "to attain higher net income to the Treasury" from the development of power, rather than to encourage widespread use at the lowest possible rates to consumers consistent with sound business principles.

The Panel would exclude indirect benefits from project evaluation and evaluate social and economic benefits in terms of dollar benefits to immediate beneficiaries only.

Further, and most important, if the Panel's recommendation on a uniform national policy were adopted, it would stop dead any proposed new authorizations. Such a proposal does not appear to appraise realistically the likelihood or unlikelihood of attaining a uniform national policy in the foreseeable future. I do not believe that the people of the United States, or the Congress, would countenance for very long any proposal to completely stop all development pending the adoption of a uniform national policy, however greatly needed that may be.

Suretyship . . .

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approached but not equaled. This is necessary because, if the economies inherent in construction by contract are to be achieved, new contractors must be found to replace those who leave the industry, and provision must be made for qualified contractors to develop and step up their capacity. In this sense, bonds operate similarly to the apprentice training program of the Associated General Contractors of America, Inc. As one of the largest and most responsible contractors in America stated recently,

> Though once a poor and struggling concern, we have always been meticulously careful to keep our financial house in order and our cards on the table. In early times we were favored with bank credit and surety bonds when we had little to show for it except ambition, muscle and honesty. The surety firm that bonded us then, still bonds us today, when our millions in bonds must be "joint-ventured" through this firm to many others. We value highly the great free-enterprising financial institutions that are essential vertebrae in the backbone of American business.

Summarizing, we have seen that the basic purpose of bonds is to indemnify against loss, but that their corollary effects of cost reduction, loss prevention, stabilization and know-how are of equal value and importance.

Nobody appreciates more than the surety business that this great country has been built by a host of honest and capable citizens known as contractors and engineers. They stand among our nation's richest assets, for they have done the work, they have taken the risks, and they deserve the credit. The sureties claim only the small but vital role of a construction catalyst which has accelerated the amazing growth and sparked the smooth teamwork that have made American construction, and America, the envy of the world. It is almost prophetic that the initial letters of this granddaddy of the engineering societies, the ASCE, should also indicate four major partners in the all-American joint venture known as the construction fraternity: "A" for Architect, "S" for Surety, "C" for Contractor, and "E" for Engineer. We are, in truth, a fraternity, for your success is our success, and our aim like your aim is completion by faithful performance.

There is one building, however, which we pray will never be completed, and that is the building of America, for that generation which does complete it shall paradoxically have defaulted. Generations defaulted once before at Babylon and Nineveh—the so-called "Garden of Eden"—because they forgot that "Except the Lord build the house they labor in vain that build it," and we modern engineers, who at this very moment are attempting to restore that ancient land, will likewise fail in that country and in our own, unless like Edwin Markham we ask:

> Why build these cities glorious
>
> If man unbuilded goes?
>
> In vain we build the world, unless
>
> The Builder also grows.

(*This article is based on the paper Mr. Higgins presented before the joint session of the ASCE Construction Division and the Associated General Contractors of America, Inc., at the Centennial Convention in Chicago.*)

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(Continued from page 249)

competent character of most maintenance organizations today, the greatest opportunity to further advance the effectiveness and efficiency of maintenance operations now lies in the attention we give to the human element.

Maintenance materials are, in general, selected in accordance with carefully prepared specifications, tested for adequacy and compliance, and carefully placed on a road in their finished form. The same careful attention is given in the selection, improvement, and operation of machinery. The future undoubtedly will bring machinery that will be even better than what we now have. It will bring materials undreamed of today. Also, no doubt, methods far superior to those in use today will be devised.

Proper blending of money, machinery, materials, methods, and men should bring about perfection in maintenance operations. Nevertheless, maintenance alone will not correct highway obsolescence. This must be done by new construction.

Yet the man who is doing the maintenance job today is identically the same in physique as the one who will do it tomorrow. Thus, the challenge to all who are charged in any way with maintaining the highways of tomorrow clearly lies in molding that man into a workman who is both capable and willing to do the job at hand. The potential for human development and improvement is unlimited.

First, of course, the man engaged in highway maintenance will want a fair day's pay for a fair day's work, comparable to that of his friend who is engaged in skilled labor elsewhere. He will want his job to be a steady one, too—not seasonal—with acceptable protection against physical injury and from the elements. And he will want economic security—protection from unjust and indiscriminate discharge, along with adequate provisions for retirement. The encouragement of individual initiative is a highly important item at all levels of operation in a maintenance organization. All personnel should have a thorough understanding of the assigned task and be busy about that task. The entire organization for maintenance operation, from the worker to the state maintenance engineer, should be composed of skilled and trained men.

And so, in one hundred years of road maintenance in this country, we have come from the axe and the pick and the shovel, from the plow pulled by oxen and horses, and from men with limited skill and knowledge, to today's vast array of equipment and materials in the hands of skilled and trained workmen and engineers maintaining hundreds of thousands of miles of highways for the benefit of millions of vehicles.

Today, as we look ahead, there are many questions. Can we as highway maintenance men keep pace with the men who are building motor vehicles? Can we find ways to repair the roads as the number of vehicles using them increases? Never was the challenge any greater, but highway maintenance men will meet it.

(This article is based on the paper presented by Mr. Whitton before the Highway Division session presided over by William N. Carey, Jr., secretary of the Division's Executive Committee, at the Centennial Convention in Chicago.)

Municipal refuse . . .

This article begins on page 127

(*Continued from page 134*)

services, or one route, per day, a single truck can handle 1,770 (3×590) services per week with twice-per-week collection, or three routes, one each on Monday and Thursday, Tuesday and Friday, and Wednesday and Saturday. Assuming 20 percent of the commercial services are included in the residential routes as "neighborhood" business services, $\frac{12{,}120}{1{,}770} \cong 7$ trucks will be required to service the 21 residential collection routes.

The commercial refuse truck requirements are found in a similar manner. Based on 250 lb of refuse per service per week and six collections per service per week, a truck can handle $\frac{7.10 \times 2{,}000 \times 6}{250} \cong 340$ services per day, or 170 services per trip. Since there are 480 strictly commercial services, $\frac{480}{340} \cong 2$ trucks will be required to serve the commercial district.

Thus a total of 9 trucks working six days per week will be necessary to handle the refuse collection problem.

Assuming a density of combined garbage and refuse in a packer-type collection vehicle of 460 lb per cu yd is obtained, a $\frac{3.55 \times 2{,}000}{460} \cong 15$- or 16-cu yd packer body should be used.

The operation will require 18 refuse collectors on a 48-hour week, or approximately 22 men on a 40-hour work week.

The estimated cost of collection and disposal with the above system is \$7.14 per ton. To obtain the total cost of the refuse activity, allowances must be made for administration and overhead such as employee benefits, retirement, insurance, and taxes. Assuming 10 percent of the total cost of the refuse activity is attributed to administration, the total cost, exclusive of overhead, will be $\frac{7.14}{0.90} =$ \$7.93 per ton.

The annual production of residential refuse is

$$12{,}120 \times 48 \times 52 \times \frac{1}{2{,}000} = 15{,}150 \text{ tons}$$

and, of commercial,

$$480 \times 250 \times 52 \times \frac{1}{2{,}000} = 3{,}120 \text{ tons.}$$

The estimated total annual cost of refuse collection and disposal is then

$$\$7.93 \times 18{,}270 = \$144{,}880.00.$$

This investigation was carried out as part of the University of California Sanitary Engineering Research Project under the general direction of Prof. Harold B. Gotaas, M. ASCE, Project Director. Special credit is due Vinton W. Bacon, A.M. ASCE, Harvey F. Ludwig, A.M.ASCE, and Raymond V. Stone, Jr., J.M.ASCE, for their valuable assistance in the organization of the field studies.

Officials and administrative officers of the 13 California cities, several private organizations, and personnel of the Bureau of Vector Control of the California State Department of Health, have rendered excellent cooperation in the field investigations. The valuable assistance rendered by numerous undergraduate and graduate engineering students in the conduct of the field studies is also gratefully acknowledged.

(*This article is based on the paper presented by the authors before a joint session of ASCE's Sanitary Engineering Division and APHA's Engineering Section, presided over by Prof. Rolf Eliassen, M. ASCE, at the Centennial Convention in Chicago.*)

Timber bridges . . .

(Continued from page 171)

appeared at first to solve the roadway flooring problem because it was lightweight and rigid, and had a good riding surface. However, replacement became a major task and it was difficult to protect it from the wear and tear of traffic. Use of this deck today is generally limited to bridges on secondary or lightly traveled roads.

Probably the next important step was the introduction of the composite structure, in which timber and concrete are combined. By proper bonding of the timber stringers to the concrete roadway slab with shear keys, an economical T-beam design resulted which gave a satisfactory slab that did not have to be replaced during the life of the structure. Another type of composite design which has been used quite extensively is a solid, laminated, timber-slab span running parallel with the roadway. For a topping, a concrete slab is attached to the timber slab by shear keys to assure composite action.

Stronger Fastenings Developed

The first timber joints and splices were made with wooden pegs, and later ones with iron bolts and nails. Then the steel gusset plate, to which the members were attached with bolts, was introduced. Steel shear blocks notched into the member were used in tension splices, but this reduced the net section considerably.

With the development of the ring connector, timber fabrication for highway bridges took on new life. This type of joint eliminated most of the weaknesses of the other types of joints and is now generally accepted.

Glued, Laminated Lumber

Perhaps the latest, and one of the most important, developments that directly affects the highway bridge is glued, laminated structural lumber. The adhesive used to form the laminations into one piece resists exposure to weather and pressure treatment. Curved chords and arch ribs are fabricated by bending relatively limber planks to shape, and gluing them into one piece while they are held in this position.

Glued, laminated timber has been a successful substitute for the now hard-to-get dense structural-grade timbers in the larger sizes and longer lengths. Also lumber of a lower stress grade can be inserted in that part of a member not subject to high stresses. The top and bottom laminations of a beam subject to high flexural stresses would be composed of a dense structural grade, whereas those near the center of the beam could be of a lower stress grade.

Thus timber has played an important role in the development of highway bridges and continues to do so by progressive improvements and developments in its manufacture, fabrication, and treatment. Engineers should not make the mistake of taking timber highway bridges off their list.

The writer wishes to give credit for the information on the early bridges to his friend and fellow highway bridge engineer, Llewellyn N. Edwards, M. ASCE, recently deceased.

(This article is based on the paper presented by Mr. Archibald in the Wood Symposium, held jointly by the ASCE Structural Division, AREA, ASTM, and ASME, at the session presided over by George E. Brandow, M. ASCE, at the Centennial Convention in Chicago.)

Good concrete . . .

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procedures followed. The following precautions should be taken:

1. Use equipment which permits ready observation of the concrete consistency in the drum when it arrives at the job site.
2. Mix only two-thirds of the required 40 to 60 revolutions at mixing speed at the beginning of the trip and hold back a portion of the required mixing water.
3. Finish the trip with the drum revolving at agitator speed.
4. On arrival at the job, bring the mix to proper consistency by adding the remaining tempering water.
5. Install an indicating and totalizing water meter between mixer drum and water supply tank.
6. Provide each mixer with a revolution counter.
7. Exercise particular care in the charging and discharging operations.
8. Do not use the concrete from a single load at several locations as this will result in excessive slump loss and non-uniformity.
9. Paint mixer drums white and keep clean to minimize excessive slump loss in hot weather.
10. Keep materials cool in hot weather.

In the final analysis, good equipment and efficient plants alone will not turn out concrete of uniformly high quality. In the first place, those in responsible charge of the work must recognize the importance of, and necessity for adequate control, down to the smallest detail, and intelligent operation.

Most important of all, the operators must take pride in their work and exercise unremitting care. If it is felt that such personnel are difficult to find under present-day conditions, we can turn back a couple of thousand years and find that conditions haven't changed much. Frontinius, Water Commissioner of Rome, wrote in A.D. 97:

Nor is greater care required upon any works (masonry), than upon such as are to withstand the action of water; for this reason, all parts of the work need to be done exactly according to the rules of the art, which all the workmen know but few observe.

All photographs are by courtesy of the U.S. Bureau of Reclamation.

(*This article was prepared from the paper by Mr. Blanks presented at a Construction Division session presided over by A. H. Ayers, chairman of the Division's Executive Committee, at the Centennial Convention in Chicago.*)

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Side Dump Truck Bodies

A LINE OF SIDE DUMP truck bodies for heavy duty applications is announced. Known by the descriptive name "Roll-Over," these are available in a wide variety of sizes and capacities. Entirely mechanical in operation, Roll-Overs dump to either right or left side, as desired. Bodies are of 10 gauge steel, can be mounted on all standard trailers, and will withstand the most severe service. The self-contained subframe consists of three heavy box type outrigger cross members. Front and rear outriggers are built with a series of gear-like teeth which roll inside the formed channel tracks welded to the body. This construction locks the body in a stationary position and prevents forward or backward movement of the body on the subframe. Main locking mechanism is a down-pull spring-loaded type plunger pin which engages in a socket built into an angle welded to the head of the body. Lock pin is actuated by a lever mounted to an A-type frame welded to the front of the subframe. Lever can be operated from either side of body. To effect dump operation, driver disengages the spring lock

Roll-Overs

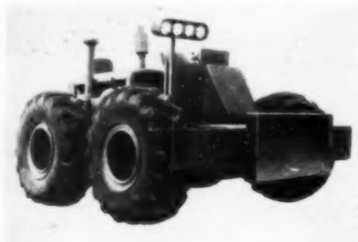
chain on the opposite side of the body to which load is to discharge, then releases plunger lock lever. Bodies can be righted manually or by a slight snaking movement of the truck. Roll-Overs, are perfectly adapted for a wide variety of material handling operations. They are particularly recommended for use on general construction projects, coal shipping, metal mining, quarrying, barge loading, stockpiling, etc. **The Galion Allsteel Body Co., Galion, Ohio.**

Quick Setting Cement

SECURELY FASTENING machinery, hand rails, seats or equipment of any type to concrete by means of anchor bolts—or permanently repairing chuck holes and breaks in concrete floors—can now be done quickly, easily and safely with Por-Rok quick setting cement. It successfully rereplaces critical lead and sulphur for most bolt-setting operations. Applied cold, there is no heating hazard, and it requires only a few minutes to set up. Por-Rok is self-bonding, self-leveling, oil-resistant, and does not shrink. It attains a compression strength of 4500 lbs psi within one hour. **The Hallemite Manufacturing Company, 2446 West 25th St., Cleveland 13, Ohio.**

Pusher Unit

A PUSHER UNIT called the Tournatractor, for contractors who are using dozers exclusively as pushers, is being offered. The pusher is a new version of the Super C Tournadozer with the dozer blade, power control unit, A-frame and dozer controls omitted. In place of these is a massive billet, 3 in. by 15 in. and spanning



Tournatractor

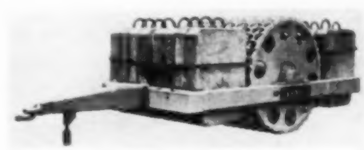
the width of the machine. On the billet the manufacturer has placed a large pusher plate. The Tournatractor can be equipped with a torque-converter as original equipment and is equally adaptable to pulling operations, either with a rear power control unit or with its drawbar alone. If later the need for a dozer develops, the billet and pusher plate can easily be removed and the A-frame, power control unit and dozer added. **R. G. LeTourneau, Inc., Peoria, Ill.**

Liquid-Level Control

AN ELECTRICAL SYSTEM for sewage and water level control and indication has been announced. Called Thermasul, the system can be used in wet wells, sumps, reservoirs, elevated tanks, standpipes, etc., and will control pump motors, pump motor speeds, and supervisory and alarm circuits. Basically, the Thermasul element consists of a temperature-sensitive, sintered-sulphide compound around which is wound a resistance heater; the whole assembly hermetically sealed in a stainless-steel tube. In air, resistance of the element is low because the heater keeps the level detector approximately 280 degrees C above the ambient air temperature. When the detector is immersed in liquid, however, the heat is conducted away and the resistance of the element jumps up rapidly, operating a small, remotely-located relay. Thus, the Thermasul element acts as a switch, opening and closing the relay with the presence or absence of liquid. The relay, in turn, can be used to control pump motors, and circuits for alarm, supervisory, and control equipment. With the addition of standard accessories, Thermasul permits great versatility in pump programming. **General Electric Company, Schenectady 5, N. Y.**

Grid Roller

AN ENTIRELY NEW METHOD of economical bituminous highway salvage and repair is now possible by means of a revolutionary tool, called the Grid Roller. The tool is designed for towing behind a motor grader or tractor and is based on the latest techniques and knowledge gained from actual field experience in the past three years. The Grid Roller solves the problem of salvaging bituminous roads, regardless of age, by its three-way action. It disintegrates the old mat material, compacts the base and rolls the new surface. In the Grid Roller, two methods of counterweighings are available to increase its adaptability. The Grid Roller may be counterweighed with reinforced concrete, T-shaped weights weighing about 1125 lbs each, shaped to fit in slots in the frame which will hold up to 16 pieces. By changing the number of concrete sections the total weight can be varied according to the requirements of the particular operation. Also available as optional equipment is a set of counterweight boxes with total capacity of about 16,550 lbs of scrap metal. The Grid Roller so equipped has an approximate gross weight of 30,000 lbs.



Three-Way Action

Other features include grids that are solidly welded to the wheel side plates. The hardness of the grids have been increased to about 340 Brinell to give them the best combination of wear resistance and toughness. The wheels are on two independent shafts, which allows the two wheel sections to be serviced separately. **Hyster Company, 2902 N. E. Clackamas St., Portland 8, Ore.**

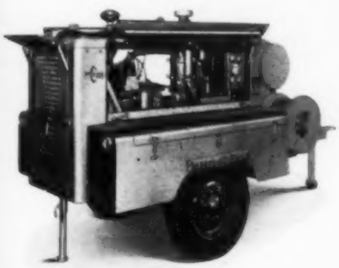
Waterproofing Compound

DASHIDE, A TRANSPARENT liquid, until recently under test by the U. S. Bureau of Standards, is claimed to be the only exterior wall waterproofing compound that actually will withstand hurricane-driven rain and water even years after application. Dashide is completely colorless. Brushed or sprayed on, it penetrates $^1/_4$ in. to $^1/_2$ in. into the wall surface, depending on porosity. It breaches and seals all hairline cracks, with no effect on the outward appearance of the walls so treated. It has proven completely resistant to acids, alkalis and temperature extremes without checking, cracking or peeling. **Dasco Chemical Co., Inc., Baltimore, Maryland.**

Equipment, Materials & Methods (Continued)

Portable Compressors

A LINE OF GYRO-FLO portable compressors with three sizes in addition to the widely acclaimed 600 cfm model is announced. The introduction of 315, 210, and 105 cfm units makes the advantages of the rotary sliding-vane design available for a wide range of operating requirements. Major benefits are simplicity and low cost of operation and maintenance, and greater reliability. Smaller dimensions, greatly reduced weight, and discharge temperatures at least 100 degrees lower than conventional portables are other important advantages. The two-stage, oil-cooled, rotary sliding-vane compressor design of the Gyro-Flo machine eliminates most of the problems of reciprocating units for portable service. There are no valves to leak, no pistons, rings, rods or clutch to wear. Air, discharged at less than 200 percent under normal operating conditions, together with thorough oil separation, eliminates hose deterioration caused by heat and oil. The continuous rotary action provides a steady flow of air without pulsations or vibrations. It is equipped with "Air Glide" capacity control, the only stepless system that controls the air output smoothly over the full range from 0 to 100 percent capacity. This combines variable intake unloading of the compressor and "floating speed" control of the engine. Throughout the entire capacity range the air pressure stays between 100 and 110 psi, assuring uniform work and more work done by drills and other air tools. The 600 cfm model is powered by a General Motors diesel engine. The 315 and 210 cfm sizes offer a choice of either GM diesels or Continental Red Seal gasoline engines. The 105 uses a Continental gasoline engine. **Ingersoll-Rand Company, Dept. PC, 11 Broadway, New York 4, N. Y.**



Gyro-Flo 105

When Requesting Literature, Please Tell The Manufacturers You Saw Their Products Mentioned in Civil Engineering

Equipment, Materials & Methods (Continued)

Shovel-Type Scoop

POSITIVE HANDLING of free-flowing or loose materials is speeded by the Towmotor Scoop. Typical bulk loads that can be quickly picked up and transported in the shovel-type scoop include coal, ore, foundry sand, cement, chemicals and many kinds of scrap. Easily tripped for gravity dumping at varied heights, the Towmotor scoop is specially suited to operation in close quarters. **Towmotor Corporation, 1226 E. 152nd St., Cleveland 10, Ohio**

Towmotor Scoop

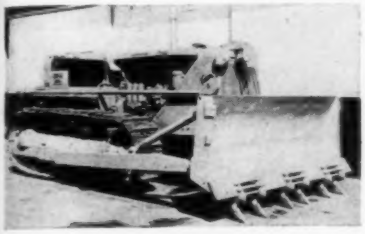
Chromium Stainless Steel

TYPE 430 CHROMIUM stainless steel is providing the answer to the shortage of quality corrosion resistant roof drainage equipment. A superior gutter and downspout material featuring durability and non-staining attractiveness, it is free of government controls and is readily available to the building trades. Marketed in a variety of standard sizes and shapes, chromium stainless roof equipment is easy to fabricate, strong and durable. Its extra strength enables it to withstand ice and snow loads without sagging, to resist buckling and cracking from extreme temperature changes. There are other advantages as well: soot, dirt, and roofing gravel wash over roof drainage equipment, often wear softer materials thin, especially in valleys and elbows. The hardness and abrasion resistance of chromium stainless steel gutters and downspouts is a valuable aid in overcoming such troubles. Nor does chromium stainless show the loose soluble oxide formation that other materials show. It exhibits no staining or streaking. This means that paint won't wash off the surface of the equipment because of corrosion or bleeding of the metal underneath. Maintenance procedures for stainless gutters and downspouts can be held to an absolute minimum. **American Iron & Steel Institute, 350 Fifth Ave., New York, N. Y.**

Equipment, Materials & Methods (Continued)

Removable Rippers

A FASTER METHOD for simultaneous blacktop removal and ground releveling is being used on the 160 acre job at Camp Beale, Marysville, Calif. Caterpillar



dozer blades are equipped with Hensley removable rippers that rip blacktop loose and stack it in piles during the releveling operation. The tractor assembly is equipped with the removable ripper teeth, D8 rollers, and dozer cutting edge and end bits manufactured by the company. **Hensley Equipment Co., 878 Joaquin Ave., San Leandro, Calif.**

Masonry and Concrete Sawing Equipment

THE FORMATION of a company to distribute masonry and concrete sawing equipment, is announced. Products will be marketed under the tradename "Target". Deliveries on diamond blades are reported immediate for masonry and concrete saws as well as small diameters for power hand saws. Target blades will introduce an entirely new system to accurately identify blade specifications for different materials. In place of the usually complex symbols, color will be used. For example; Target gold blades for hard materials, blue blades for medium and red blades for soft or abrasive products. **Robert G. Evans Company, 6315 Brookside Plaza, Kansas City, Mo.**

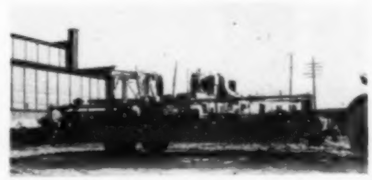
Reversal Photo Paper

A TYPE OF REVERSAL photographic paper was described at the annual meeting of the Blue Print and Allied Industries. It differs from conventional papers (such as kodagraph autopositive paper) in that the behavior of the emulsion is an entirely new concept of photography which leads to direct production of positive prints with conventional equipment and processing. The paper emulsion reacts to light in a directly opposite manner from the ordinary type of paper used by photographers. When this reversal paper is exposed to light and developed in a fogging developer, the unexposed areas turn black. In those areas which are exposed to light, the fogging action of the developer is inhibited, resulting in a positive image. **Eastman Kodak Company, 343 State St., Rochester 4, N. Y.**

Equipment, Materials & Methods (Continued)

Finishing Machine

HAVING PROVED ITSELF on the job for more than a dozen contractors the super portable Detroit finishing machine is now being made available. The Detroit Special is the ideal finishing machine for city street, expressway and airport concrete construction. The secret lies in its extreme portability. In a matter of seconds



The Detroit Special

the Flex-Plane finisher will lift itself off the paving forms onto its own built-in, pneumatic-tired "trailer". A hydraulic tongue lifter quickly spots the tongue for fast attachment to batch truck or other towing equipment. Two automobile-type pneumatic tired wheels nest in the frame of the finishing machine as it is working on the forms. When it comes time to move the machine to another job, a flick of a switch lowers the wheels and the whole machine becomes a trailer. Contractors who have used the machine claim large labor savings, as idle time while transporting machinery is cut to a minimum. The Detroit Special incorporates many other advances in finishing machines. Because city street paving calls for a variety of widths the machine was designed to be completely telescopic to conform to any width work. Machines are made in three basic sizes to finish widths from 10 ft to 27 ft. Changes in paving widths can be accomplished in one-fourth the time required by other known methods. The screeds are both mounted on the outside of the frame. This enables the machine to set lower on the forms, providing greater rigidity and greater accessibility. This feature enables contractors to easily adjust screeds for any kind of work. An offset screed attachment is provided for contractors who contract for integral curb work. The attachment rough forms the curbing automatically. The screeds themselves have been improved to give an infinite range of adjustment which permits not only synchronization of the front and rear screeds, but also counter-synchronization, parallel stroking, quarter parallel stroking, etc., where desirable. **Flexible Road Joint Machine Co., Warren, Ohio**

Concrete Cutter

THE MODEL 252 FELKER Di-Met concrete cutting machine featuring power drive has just been announced. A $13\frac{1}{2}$ hp Wisconsin air-cooled engine not only amply drives the diamond blade but furnishes power to the rear wheels through a stepless variable-speed reducer and fric-

(*Continued on page 271*)

Equipment, Materials & Methods (Continued)

tion drive. Speed may be adjusted from a mere crawl to a fast walk by rotating a crank. Upon actual test the power drive has doubled life of the diamond wheels by removing human variations in feeding. The diamond wheel is raised or lowered by a built-in double-acting hydraulic jack. This jack also expedites coupling the machine to a trailer hitch for towing, front wheels automatically retracting as valve is released. Depth of cut is established by an adjustable stop. The machine can be steered, rear wheel position locking after establishing line of travel. Front and rear guides are provided. The Model 252 can be purchased complete, as a basic unit having only those features necessary for cutting, or in several modifications. These include the water pump, starter, generator, battery and power drive in various combinations. **Felker Manufacturing Co., Torrance, Calif.**

Electric Crane Truck

MAINTENANCE GOES OVER with a "boom" at the new plant of Caterpillar Tractor Co. in Joliet, Illinois. A 6,000-lb capacity Yale electric crane truck equipped with articulated platform, is used for faster, easier maintenance of lighting and other overhead equipment. The crane can position the boom and platform for overhead work above machine tools

6,000-lb Capacity

and other obstacles—in locations difficult to reach by other means. In operation, maintenance man and material are picked up by lowering the boom until the platform rests on the floor. Positive mechanical linkage on the boom keeps the platform parallel with the floor at all times, regardless of boom elevation. For maximum coverage from a given aisle location, the boom can be extended to lengths up to 19 ft and swung in a 270 deg arc. This same crane truck also is used for outdoor maintenance work. **The Yale & Towne Manufacturing Company, Philadelphia 15, Pa.**

Equipment, Materials & Methods (Continued)

Stripper Shovel

SEVERAL MODELS of the hi-lift stripping shovel, recently introduced, are working in various sections of the country. Outstanding performance reports on casting operations have been turned in on the excavating unit using both 2 and $2^1/_2$ cu yd

1005 Hi-Lift

dippers, depending on digging conditions. Using the same base machine as the standard $2^1/_2$ cu yd Model 1005, the hi-lift stripper operates with a 50 ft boom and 36 ft dipper stick. This attachment allows a maximum dumping height of 40 ft and a reach of 60 ft with boom angle at 45 deg. By comparison, the standard 1005 shovel attachment, operating by chain crowd, carries a 26 ft boom and standard $19^1/_2$ ft double dipper sticks for heavy duty digging work. Features of the hi-lift design include a single dipper stick with cable crowd and a twin box section boom structure for maximum strength and minimum weight. In addition, the 1005 hi-lift can be converted for lift crane, dragline or clamshell operation. **Koehring Company, 3026 West Concordia Ave., Milwaukee 16, Wis.**

Deep-Well Water System

PRODUCTION OF A completely-packaged tank-mounted deep-well water system has been announced. The unit, called Figure 3681, is designed to fill the need for an inexpensive yet first-quality complete system for wells in which the pumping level of the water is not more than 50 ft below the pumping unit. This system has a capacity rating up to 450 gph. It measures only 33 in. long by 14 in. wide by 29 in. high, including the 17 gal galvanized tank. Operating sound, often existent in tank-mounted systems, is minimized by specially designed rubber mountings and connections. With only one moving part, quiet operation and freedom from wear are also assured. The unit's close-coupled construction allows permanent alignment of rotating parts. All cast iron parts coming in contact with water are protected with a baked-on coating to resist rust and corrosion in the pump. With its self-priming feature, the system has another

(*Continued on page 273*)

Equipment, Materials & Methods (Continued)

important selling feature. It automatically resumes operation when the foot valve is again submerged after any temporary "dry season" drop in water level. The unit eliminates the conventional stuffing box by using a modern mechanical seal. There is no radio interference from the motor. The motor also has a built-in overload protection and all ratings are within the working limits of the motor. Installation time is cut down with the unit because the suction and pressure pipes attach directly to the pump in a readily accessible position. The unit comes complete with all necessary accessories. **Goulds Pumps Inc., Seneca Falls, N. Y.**

Medium and Heavy Duty Trucks

THE TREND TOWARD lighter but more powerful trucks for highway and off-highway haulers went sharply forward today with the announcement of new GMC medium and heavy duty truck models. Introduction of four GMC diesel models and many important developments for greater operating economy and driver comfort were highlights of the 1952 GMC 400 and up series models announced. Three of the new GMC diesels were six-wheelers to meet the growing demand for this type of unit by highway haulers, while the fourth diesel model was introduced to answer the need for light-

Model DW620-47

weight, low-cost diesel power in the 21,000 lb G.V.W.—45,000 lb G.C.W. trucking field. Weight reduction in one of the GMC model series averaged as much as 865 lbs lighter than the former models. Significant developments in the GMC models were: shortening of all heavy duty models from bumper to rear of cab to allow use of longer trailers in 45-ft length limit states; electric shift introduced as standard equipment on all GMC trucks of the 450 and up model series having two-speed axles; and new lightweight, load-cushion springs with fewer but thicker leaves, adding to driver comfort and load safety through smoother ride. A 4900 series Synchromesh transmission is being introduced in all models that previously used the 4450 Synchromesh. It incorporates many precision features for increased performance and longer life. **GMC Truck & Coach Div., General Motors Corp., 660 South Boulevard, East, Pontiac 11, Mich.**

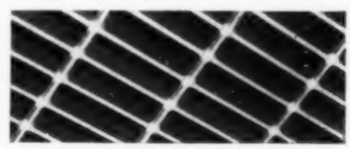
Equipment, Materials & Methods (Continued)

Centrifugal Pump Test Stand

THE FIRST 12 MONTHS of operation of several pump test stations has recently been completed. These stands are engineered to give a complete reproduction of performance for pumps of all sizes and ratings. They employ the most modern test techniques and offer accuracy difficult to obtain with previous test procedures. They are permanent installations consisting of a double-ended dynamometer mounted on an automatic lift between two pre-aligned pump bedplates. Some of the main features include: special couplings; quick-operating adapters for pipe connections; special flexible hose for discharge connections; permanent, calibrated venturis; motor operated valves and a pipe system that requires no priming and is free of air locks. The test engineer operates the pumps and conducts the complete tests from a main control desk where he has a clear view of all instruments. In running a test the customers operating conditions are simulated at the control desk. The test engineer then operates the pump at rated speed of the customers motor and records data for a minimum of 6 test points. Readings of pressure, flow and power input are taken only after conditions are stable. By conducting tests in this manner, with laboratory instruments, the calculation of test results can be made without the need of theoretical corrections. This assures that the pump satisfactorily meets the specified conditions of total head, rate of flow and horsepower required. **De Laval Steam Turbine Company, Trenton 2, N. J.**

Welded Grating

AN OPEN STEEL WELDED grating called Klemp-Krest has been produced. The welded grating features round steel cross bars so formed as to provide a peak, or crest, on the top side of the bar. These bars are placed at right angles on top of flat bearing bars set on edge and then electro-welded under great pressure. The crested cross bar adds many advantages. The roundness of the bar which forms cross braces between the bearing bars gives greater tensile strength and makes a stronger weld, thus effecting perfect distribution of load, or impact, in every direction over the area of each section. The crested top provides a ridge between each bearing bar; thereby not only making this grating increasingly safe to walk on, but adding maximum non-slip characteristics. **Klemp Metal Grating Corporation, 1371 North Branch St., Chicago 22, Ill.**



Klemp-Krest

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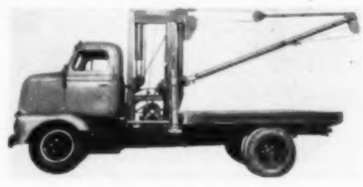
Equipment, Materials & Methods (Continued)

Hydraulic Truck Crane

THE HYDRA-LIFT, a recently developed crane with hydraulically powered boom that can be mounted on the frame of any truck, 1-1/2 tons or larger, is now in production. The Hydra-Lift, Model B, features a variety of improvements over the original production model. It requires but 40 in. behind the cab of a truck, has a load-line capacity of 6,400 lbs and a swinging



Hydra-Lift

boom which telescopes from 12 to 17 to 22 ft. The two chief improvements are; a big increase in the unit's safety margin, and the fact that it now is shipped almost completely pre-assembled. Briefly, safety margin has been increased by raising about 18 in. the point on the crane's mast where the topping cable is anchored. This results in a wider angle between the boom and topping cable, giving the boom a much better lifting advantage. Other changes which have given the crane a new look and improved its operation are the addition of a bail bar on the topping cable and replacement of the old hammerhead boom-tip casting with a new casting of swivel design. The bail bar serves to strengthen the topping cable rigging. The swivel boomtip casting permits use of the Hydra-Lift in closer quarters, since even though a load is at an angle to the boom it can be winched in with no damage to the winch cable. Other improvements include lever controls, rather than the push-pull type, for easier operation. Also, a special set of controls for operation of the Hydra-Lift outside the cab is available. **Pitman Mfg. Co., 300 West 79th Terrace, Kansas City 5, Mo.**

Expanded Metal Walkway

SAFE-T-MESH WALKWAYS and stair treads that permit easy access to all points requiring process inspection or maintenance are used in the Cedarapids Mixing Plant. Safe-T-Mesh is made by slitting and stretching heavy gauge sheet steel into a durable, non-skid diamond-pattern surface. It is welded permanently into sturdy angle iron frames to form the walkways and treads. Advantages in applications such as this are its high strength weight ratio, weather-resistance, and through-visibility. Its skidproof surface prevents accidental slipping and falling, and the open work pattern allows passage of water, dirt, and dust particles that otherwise would accumulate and make walking surfaces slippery and dangerous. **Wheeling Corrugating Co., Wheeling, W. Va.**

Spreader

PRODUCTION OF THE MODEL 100 Jersey spreader, a tractor mounted stone spreader with capacity to handle up to 20 tons per minute, has been announced. The Jersey spreader features an exclusive strike-off adjustment that permits varying depths of spread from a minimum of 1 in. up to 12 in. Adjustable bleeder gates allow a variable width of spread from 10 ft to 13 ft in 3 in. increments. The Model 100 is designed for use with the heavier crawler-type tractors and is mounted on the push beams of the dozer after the blade has been removed. No special accessories or attachments are required for feeding stone from any type dump truck directly into the hopper. The truck is backed up to the hopper and the body raised. The forward movement is controlled by the tractor operator as the truck, steered by the driver, is pushed along. The Model 100 Jersey spreader handles stone of any size from 1/4 in. up through the normal macadam range and certain subgrade materials. Overall width is 12 ft; overall height 48 in. and weight (without tractor) 4,200 lbs. **Tractor Spreader Co., Hasbrouck Heights, N. J.**

Concrete Mixer

INCREASED HORSEPOWER and several other features have been incorporated in the 1953 Model 6-SE trailer type concrete mixer, it was announced. The recently designed, end-discharge, one bag model now uses a two-cylinder air-cooled

Model 6-SE

engine developing 10 hp at 2,000 rpm compared to 8 hp for the single cylinder engine used on the old model. This 25 percent boost is largely due to an increase in the piston displacement from 38.5 cu in. to 45.9 cu in. In addition, the mixer incorporates a cam operated skip shaker and a tongue and legs that fold completely out of the way for shipment. The Model 6-SE mixer retains the steepest skip angle of any mixer having a full 60 deg angle in the discharge position. **Knickerbocker Company 638 Liberty St., Jackson, Mich.**

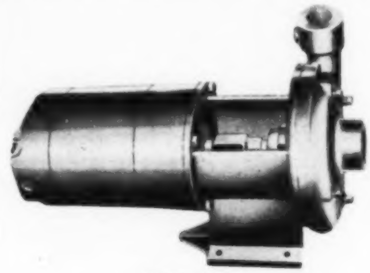
Automatic Hi Pressure Booster Gun

THE AUTOMATIC HI PRESSURE booster gun, Model 1120, is designed for the following applications: lubrication of bearings on industrial machinery requiring injection of a small quantity of lubricant at extremely high pressure; an auxiliary high pressure lubricator to service bearings requiring injection of limited quantities of special purpose lubricants; cracking "frozen" or clogged bearings on contractors' equipment without the use of power-operated gun. Gun provides complete range of pressures up to 10,000 psi. Easy one-hand push action eliminates fatigue—weighs only 2 lbs. Long, hydraulic coupler extention permits reaching deep-seated and hard-to-reach fittings. Handles all pressure gun lubricants in any weather. Holds 2-1/2 ozs., can be refilled in seconds by engaging filler fitting on gun with control valve on hose from power—or manually operated pump. Gun can be cleaned by removing only one outlet check—no packings to replace. **Lincoln Engineering Company, 5702–43 Natural Bridge Ave., St. Louis 20, Mo.**

Equipment, Materials & Methods (Continued)

Centrifugal Pump

A LOW COST GENERAL PURPOSE centrifugal pump has just been placed on the market. It is called the Series AM pump and is designed primarily for economical pumping of large capacities at moderate heads. It is especially suitable for use with air conditioning systems and circulating water for cooling towers. The AM Series pump may be used for sprinkling lawns, pumping for swimming pools, and many other industrial or agricultural duties. Special all-bronze pumps are available for pumping brine or other corrosive liquids. Sizes range from 1/4 through 5 hp. **Jacuzzi Bros. Inc., Richmond, Calif.**



Series AM

Spreader

A REVOLUTIONARY NEW center-spread self-unloading truck body called the Spread-Mobile is announced. The most outstanding feature, is the location of the distributor plate at the left center of the chassis beneath the forward end of the body, instead of at the rear. This complete reversal of the design of all previous spreader bodies has a very important advantage. The skid-proofing material is spread ahead of rear wheels and well under the front wheels, thus assuring far better traction for the truck under all conditions than ever before possible. Another vital feature of the Spread-Mobile is its exclusive, patented self-heating system which prevents the freezing of the conveying and spreading mechanism, as well as the contents in the lower part of the body. This arrangement utilizes the heat of the truck's own exhaust by channeling the exhaust through an enclosure which runs under the entire length of the body; and surrounds the lower portion of the conveyor. If the material is warm when loaded; this exhaust heater will keep it free-flowing throughout the trip. By the time it reaches the conveyor and is carried to the spreader, the material penetrates easily into the ice for more efficient skid-proofing. In addition, the heater prevents the mechanism from becoming brittle in the cold, thus eliminating a common source of breakage. All controls are centralized at the driver's seat to permit efficient one-man operation. **Baughman Mfg. Co., Jerseyville, Ill.**

Literature Available

MULTI-PURPOSE HOSE—An 8-page pamphlet in four colors describing the "Basic Five," color-coded, multi-purpose industrial base line is announced. The five hose types in the new line replace 18 hose types offered formerly. Stocks of many different hose types are no longer required. Inventories can be reduced. The publication gives details of construction, sizes, lengths, pressures, recommended couplings and uses for the new hose line. **The Thermoid Company, Trenton, N. J.**

SHORTCUTS FOR PRODUCTION, CONSTRUCTION, ETC.—The 64-page "Idea Book" on uses of hydraulic tools and hand tools, is offered. The book pictures a collection of new applications for this equipment in production, maintenance, construction, laboratory and other fields. Featured are tested uses for "Porto-Power" remotely-controlled hydraulic jack equipment and related products which introduce new ease, savings and safety to a great range of routine and special operations. **Blackhawk Mfg. Co., Milwaukee 1, Wis.**

TRUCK MIXER—The Rex Adjusta-Wate Moto-Mixer Bulletin, No. 52-32, is pictorially described in detail and is now being released. This bulletin describes how effectively maximum legal payloads and complete flexibility in ready-mix operations can be obtained. The "Hidden Treasure" feature—the most valuable legal payload space on a truck is located directly behind the truck cab, and shows what its uses mean to mixer owners and operators. **Chain Belt Company, Adv. Dept., Milwaukee 1, Wis.**

MAINTENANCE GUIDE—Maintenance practices are simplified for operators of Cat DW21, DW20 and DW10 tractors in a multi-colored cartoon-type booklet being issued. Using scenes familiar to the operator, the booklet discusses factory-prescribed techniques in caring for Caterpillar wheel-type tractors. Reduction of repair bills and elimination of "down time" is the purpose of the booklet which deals with many specific procedures in connection with routine Caterpillar engine maintenance. **Caterpillar Tractor Co., Peoria 8, Ill.**

SLIP-ON FITTINGS—A bulletin, No. 145, on Nu-Rail slip-on fittings is offered. The fittings are used in the construction of permanent and temporary pipe structures, saving 80 percent on labor, as much as 30 percent in overall cost, when compared to conventional threaded pipe and fittings. The fittings have been used extensively in the construction of all types of railings, pipe enclosures, racks, shelving, scaffolding, advertising displays and many other uses. Specifications, dimensions and other data are included. **The Hollander Mfg. Co., 3841 Spring Grove Ave., Cincinnati 23, Ohio**

Literature Available (Continued)

Heavy-Duty Excavator—A bulletin on a popular, heavy duty excavator, the Model 955-A, a "rock-rated" machine in the 2-1/2 yd class, is announced. Numerous photographs of the P&H 955-A working on a variety of projects throughout the country are supplemented in the 40-page, two-color booklet with close-up pictures and data describing the features of the excavator. Special mention is given to P&H's exclusive Magnetorque Swing which has won wide acceptance in the construction industry because of its speed, smoothness and reduction of maintenance. Ask for Bulletin X122-1. **Harnischfeger Corporation, Large Excavator Div., Milwaukee 46, Wis.**

Air-Entraining Agent for Concrete—A folder decribing the advantages of using Vinsol air-entraining agent in concrete is available. The folder briefly lists the advantages of air-entrained concrete and the methods employed in its production. The use of neutralized Vinsol solution is covered in a series of questions and answers. The leaflet points out that although Hercules does not supply solutions of neutralized Vinsol, these solutions can be obtained from numerous companies in all parts of the country. A list of these suppliers is included in the leaflet. . **Hercules Powder Company, Wilmington, Delaware.**

Dryer-Mixer—An 8-page, two-color bulletin on the Mixall, portable, one-unit, dryer-mixer has just been released. Describing the Mixall as the answer to the urgent need for quality hot patch material, the bulletin briefly outlines the reasoning behind the design and development of the new machine. Design and operating features, such as grouped controls, low 14 in. loading height, and all-welded channel steel frame are pictured and described. Condensed specifications are included on the component page. Elsewhere in the booklet is shown the high discharge feature that makes charging a wheelbarrow easy. The Mixall bulletin brings out several allied usages for the equipment that should be of interest to contractors. Ask for Bulletin 804. **Barber-Greene Company, Aurora, Ill.**

Petroleum Catalog—A 4-page catalog entitled, "Klemp 4 Grates Serving the Nation's Major Oil Companies", describes the construction of Klemp-Krest welded grating which incorporates a crested cross bar between the bearing bars to provide maximum non-slip characteristics. Catalog contains technical information including engineer's diagrams, a safe load table on their welded and diamond riveted grating, and a detailed diagram on the installation of their two patented products, Hexteel and Floorsteel, for ganister linings. **Klemp Metal Grating Corp., 1371 North Branch St., Chicago 22, Ill.**

Literature Available

Welded Grating—A new type of open steel welded grating is announced in a 24-page "Open Steel Grating and Stair Tread Catalog." It is fully illustrated and complete with engineering data, charts, and a safe load table for welded and diamond riveted grating. **Klemp Metal Grating Corp., 1371 North Branch St., Chicago 22, Ill.**

Road Reclamation Method—A 24-page booklet, giving detailed information on an economical method of road rebuilding using existing materials in worn-out roads, has just been made available. The profusely illustrated book gives a step-by-step procedure for reclaiming bituminous and gravel roads and streets, plus useful production data, rock hardness charts, cost estimates and actual job costs. Contractors, state, county or city officials, or any person actually engaged in road rebuilding, can obtain a copy of this booklet, titled, "The Athey Method of Reclaiming Worn-Out Roads." **Athey Products Corporation, 5631 West 65th St., Chicago 38, Ill.**

Water Storage in Elevated Steel Tanks—Modern water storage in elevated steel tanks is the subject of a 20-page brochure. With some 50 installation photographs, the bulletin presents data on five types of elevated steel tanks. Included for each type is a table which gives tank dmiensions and other data for the various sizes available. A section of the brochure is devoted to accessory equipment. New tanks for old towers and foundations also are discussed briefly. **Pittsburgh-Des Moines Steel Co., Neville Island, Pittsburgh, Pa.**

Scraper Line—A booklet on the scraper line produced by the company, has just been released. It will be of particular interest to heavy equipment men in the construction and mining fields. There are more than 20 illustrations, including photographs of actual working conditions and drawings showing the particular features of "Cat" scrapers. Ask for Form No. 30375. **Caterpillar Tractor Co., Peoria, Ill.**

Lubrication & Maintenance Guide—The revised 4th edition of the company's lubrication and maintenance guide for contractors' equipment has just come off the press. Called "Lubrication & Maintenance Guide for Contractors and Allied Equipment," this handy pocket-sized booklet contains 96 pages of up-to-date information on the lubrication and maintenance of equipment for quarries, crushed stone plants, sand and gravel plants, asphalt plants, and ready-mixed concrete suppliers, in addition to contractors' equipment. **Gulf Oil Corporation, Gulf Refining Co., 719 Gulf Bldg., Pittsburgh 30, Pa.**

PROCEEDINGS AVAILABLE

The following papers, printed as Proceedings Separates, may be ordered on the basis of summaries given in this and previous issues of CIVIL ENGINEERING. Discussions of these papers will be received, as in the past, for a period of five months following the date of issue. A summary of each paper appears in several consecutive issues; other titles will be added every month, as they become available. Use the convenient order form on page 284.

Summarized in Earlier Issues

128. **Horizontally Curved Box Beams,** by Charles E. Cutts.

129. **Analysis of Arch Dams of Variable Thickness,** by W. A. Perkins.

130. **Underground Corrosion of Piping,** by R. A. Brannon.

131. **The Allegheny Conference—Planning in Action,** by Park H. Martin.

132. **Specifications for Structures of a Moderate Strength Aluminum Alloy of High Resistance to Corrosion, Progress Report of the Committee of the Structural Division on Design in Lightweight Structural Alloys.**

D-66. Discussion of Paper, **Lateral Forces of Earthquakes and Wind,** by a Joint Committee of the San Francisco Section of ASCE, and the Structural Engineers Association of Northern California.

D-79. Discussion of Paper, **Stage Predictions for Flood Control Operations,** by Ralph E. King.

D-80. Discussion of Paper, **Mississippi River Valley Geology Relation to River Regime,** by Harold N. Fisk.

133. **Uplift in Masonry Dams: Final Report of the Committee on Masonry Dams of the Power Division, 1951.**

134. **Solution of an Hydraulic Problem by Analog Computer,** by R. E. Glover, D. J. Herbert, and C. R. Daum.

135. **Application of Electronic Flow Routing Analog,** by Max A. Kohler.

136. **Steady-State Forced Vibration of Continuous Frames,** by C. T. G. Looney.

D-75. Discussion of Paper, **Base Course Drainage for Airport Pavements,** by A. Casagrande and W. L. Shannon.

D-76. Discussion of Paper, **Model Tests Using Low-Velocity Air,** by James W. Ball.

Third Notice

137. **Construction of the Delaware Memorial Bridge,** by Homer R. Seely.

138. **The Value and Administration of a Zoning Plan,** by Huber Earl Smutz.

139. **Nonlinear Electrical Analogy for Pipe Networks,** by Malcolm S. McIlroy.

140. **Irrigation Water Rights in the Humid Areas,** by Howard T. Critchlow.

141. **Effect of Entrance Conditions on Diffuser Flow,** by J. M. Robertson and Donald Ross.

D-86. Discussion of Paper, **Ground-Water Phenomena Connected with Spreading,** by Paul Baumann.

D-87. Discussion of Paper, **Sewage Reclamation by Spreading Basin Infiltration,** by Ralph Stone and William F. Garber.

D-92. Discussion of Paper, **Experimental Investigation of Fire Monitors and Nozzles,** by Hunter Rouse, J. W. Howe, and D. E. Metzler.

D-96. Discussion of Paper, **Surface Curves for Steady Nonuniform Flow,** by Robert B. Jansen.

D-100. Discussion of Paper, **Forced Vibrations of Continuous Beams,** by Edward Saibel and Elio D'Appolonia.

Third Notice

142. **Unconfined Ground-Water Flow to Multiple Wells,** by Vaughn E. Hansen. The purpose of this paper is to clarify the nature of unconfined flow to single and multiple wells, and to present a method of solving problems associated with this type of flow. The effect of the capillary fringe on the location of the free surface and the form of the flow patterns, the zone of validity of the Dupuit equation, the shape of the free surface near the well, and the variation in the stream-surface spacing are all discussed. A functional relationship independent of the radius of influence is established, relating the variables at the well, this relationship applies to both single and multiple wells. A fundamental dimensionless parameter consisting of a ratio of Froude's to Reynolds' number is formulated that characterizes the shape of the cone of depression around a well. The concepts of well efficiency and effectiveness are clarified and guides are presented for their correct use. (Available September 1.)

143. **Electrical Analogy in Problems of Three Dimensions,** by P. G. Hubbard and S. C. Ling. Engineers whose work includes the design of low-loss transitions of air-conditioning systems, water-supply systems, or hydraulic outlet works will be particularly interested in the experimental methods and typical results presented in this paper. The principles involved are analogous to those of the flow net or relaxation methods already used for two-dimensional work, but the requirements or symmetry about one axis are removed. An inexpensive, versatile tool of high accuracy is the result. (Available September 1.)

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144A.

144B. **Aerodynamic Stability of Suspension Bridges, Progress Report of the Advisory Board on the Investigation of Suspension Bridges.** The aerodynamic forces which act on a bridge in the wind, and the occurrence of resonance of the motion, depend on the velocity and direction of the wind and the size, shape, and motion of the bridge. The amplitude of oscillation depends on the strength, variation, and duration of wind forces and the energy storage capacity and damping of the structure. The remaining unknown factor is supplied by a test that relates the motions of a dynamic section model to a properly scaled wind. Means are discussed of designing a bridge which will be safe against objectionable oscillation in the wind. Because of its length (63 pages), this paper is rated as two Proceedings-Separates, and priced accordingly. (Available September 1.)

145. **Torsion of I-Type and H-Type Beams,** by John E. Goldberg. Beginning with a review of pure torsion and torsion bending of I-type and H-type sections, the basic differential equation is obtained for the twisting of such sections. The stresses resulting from twist—namely, the simple torsional stresses and longitudinal and shearing stresses due to warping restraints—are discussed from the engineering standpoint. Particular solutions of the differential equation are obtained for various warping conditions at the ends, and it is shown how these solutions are combined to formulate and analyze various problems, including that of a framed floor panel. (Available September 1.)

146. **Electrical Analogies and Electrical Computers: Surge and Water Hammer Problems,** by Henry M. Paynter. This paper describes the basis for the application of electrical-hydraulic analogies and electronic analog computers to problems in hydraulic transients. Water hammer studies in a uniform pipe and surges in a simple tank are discussed in some detail. In addition to promoting understanding of the underlying phenomena of unsteady flow, analog techniques are demonstrated as furnishing formulas capable of practical applications. (Available September 1.)

147. **The Delaware Memorial Bridge: Design Problems,** by Charles H. Clarahan, Jr., and Elmer K. Timby. One of the major suspension spans thus far constructed, this bridge emphasized the need for knowledge of the behavior of such structures in order that maximum economy in design may be attained. The provisions for torsional resistance in this bridge include a double lateral system. Design specifications are discussed in some detail. The solutions to problems inherent in the particular foundation conditions encountered are explained. Correlation of the design with model tests has proved helpful and these tests are being continued. (Available September 1.)

D-84. Discussion of paper, **Longitudinal Mixing Measured by Radioactive Tracers,** by Harold A. Thomas, Jr., and Ralph S. Archibald. The original paper, published in August 1951, presented a method of determining the magnitude and effect of horizontal mixing in pipes and tanks as available to the engineer through the use of radioactive tracers. Discussers are: Conrad P. Straub and Donald A. Pecsok, Alfred C. Ingersoll, Harold A. Thomas, Jr., and Ralph S. Archibald. (Available immediately.)

First Notice

148. **Bank Stabilization by Revetments and Dikes,** by Raymond H. Haas and Harvill E. Weller. Aggravated by wide variations of hydrographic and physiographic elements, the problem of bank stabilization on the Lower Mississippi River has been found to be extremely complex. The solution of the problem is not wholly a matter of applying hydraulic formula nor is it simply a proposition of adopting structural design that has proved successful elsewhere. This paper presents the problems encountered and the evolution in the design of structures employed to modify the primitive stream for the purpose of securing effective flood control and navigation. (Available October 1.)

149. **Industrial Waste Treatment in Iowa,** by Paul Bolton. Problems involved in the handling of industrial wastes contain phases peculiar to a given region, but many such problems are common experience everywhere. As in most of the states, this question has been of major concern for a number of years in Iowa, and is presented herewith to a larger audience as a challenge toward more generalized solutions. (Available October 1.)

150. **East St. Louis Veterans Memorial Bridge,** by A. L. R. Sanders. Some of the problems encountered in designing this bridge were of particular interest and importance. Their solution and the design procedure in connection therewith are explained. The cantilever river span is believed to be the longest of any span crossing the Mississippi. The AASHO specifications were departed from in the design of compression members and in determination of the wind load requirements on long spans. Other special features in the design were the bridge shoes, the floor beam hangers, and provisions for the lateral bending of floor beams. (Available October 1.)

151. **Topographic Mapping in Kentucky,** by Phil M. Miles. Modern methods of topographic mapping have been employed in an unusually extensive cooperative program between the Commonwealth of Kentucky and the United States Geological Survey. This paper describes the historical and technical facts which determined the techniques and specifications used. Use of the equipment and the filing and distribution of topographic data, with emphasis on the value of by-products, is explained. The work in Kentucky is of particular interest to engineers or state officials considering topographic mapping in their own state. (Available October 1.)

152. **Methods for Making Highway Soil Surveys,** by K. B. Woods. Important developments and refinements in methods for making highway soil surveys include the use of agricultural soil-survey maps, certain types of geologic maps, and air photos. Resistivity methods and seismic methods are useful for obtaining additional detailed information. Knowledge of geology, pedology, and aerial photography is important in interpreting the data obtained from these sources. The future need for specialists, trained in the new techniques, is foreseen as applying particularly to soils sections of the larger highway departments. (Available October 1.)

153. **Characteristics of Fixed-Dispersion Cone Valves,** by Rex A. Elder and Gale B. Dougherty. This paper reports the results obtained from field tests on five Howell-Bunger type valves that have been installed by the Tennessee Valley Authority. A usable method is described for obtaining accurate discharge ratings with a minimum discharge through the valves. Rating curves and discharge coefficients are given. The results of measurements of the air required to vent these valves are supplied and the effects of the dissipating structures that surround the valves lead to the formation of ideas of the mechanics of air demand. (Available October 1.)

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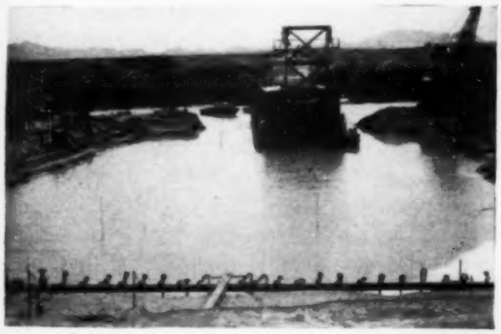

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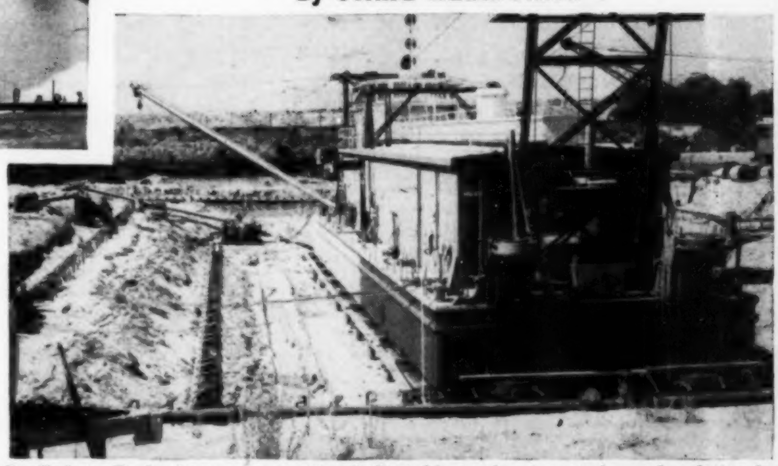

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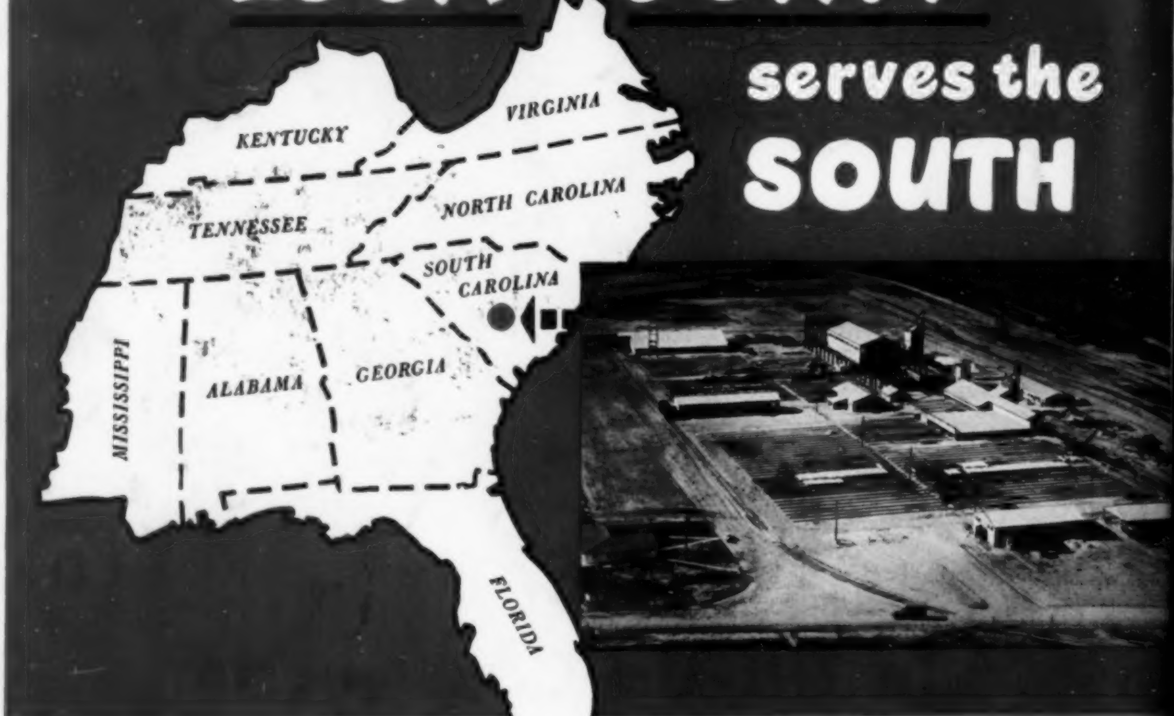

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